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Master's Thesis Dissertation

Natural User Interface Design using Multiple Displays for Courier Dispatch Operations.

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Declaration of Authorship

I, Rory M.S. Clifford, declare that this thesis titled, 'Natural User Interface Design using Multiple Displays for Courier Dispatch Operations.' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

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UNIVERSITY OF CANTERBURY

Abstract

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Master's of Human Interface Technology

Natural User Interface Design using Multiple Displays for Courier Dispatch Operations.

by Rory M.S. Clifford

This thesis explores how Natural User Interface (NUI) interaction and Multiple Display Technology (MDT) can be applied to an existing Freight Management System (FMS), to improve the command and control interface of the dispatch operators. Situational Awareness (SA) and Task Efficiency (TE) are identified as being the main requirements for dispatchers. Based on studies that have been performed on SA and TE in other time critical occupations such as Emergency Medical Dispatch (EMD) and Air Traffic Control (ATC), a substitute dispatch display system was designed with focus on courier driver and freight management systems and monitoring. This system aims to alleviate cognitive overheads without disrupting the flow of the existing CFMS by providing extended screen area matched with a natural input mechanism for command and control functionality. This Masters thesis investigates which of commercial state-of-the-art interface tools is best to use in a wide Field-of-View (FOV) multiple screen display and to dicern if there is any practical impact that a proposed NUI system will have to courier dispatching.

To assess the efficacy of such a hypothetical system the author has developed an experimental prototype that combines a set of three monitors in a Multi-Monitor System to create the overall display system, accompanied with two traditional and two advanced NUI direct and indirect interaction techniques (mouse, trackpad, touch screen and gesture controller). Experiments using the prototype were conducted to determine the optimum configuration for control/display interface based upon task effectiveness, bandwidth and overall user desirability of these methods in supporting behavioural requirements of dispatch workstation task handling. The author use the well-studied and robust Fitts's Law for measuring and analysing user behaviour with NUI's.

Evaluation of the prototype system finds that the multi-touch system paired with the multi-monitor system was the most responsive of the interaction techniques, direct or

indirect. Based on these findings, employing such an interaction system is a viable option for deployment in FMS's. However for optimal efficiency, the firmware that supports the interactivity dynamics should be re-designed so it is optimized to touch interaction. This will allow the multi-touch system to be used effectively as an affordance technology. Although the gesture interaction approach has a lot of potential as an alternative NUI device, the performance of gesture input in this experimental setting had the worst performance of all conditions. This finding was largely a result of the interface device limitation within the wide FOV display range of the multi-monitor system. Further design improvements and experimentation are proposed to alleviate this problem for the gesture tracking and for the touchscreen modalities of interaction.

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The following terms are used throughout the document to refer to certain aspects in the Freight Management System:

Dispatcher: the person or people responsible for co-ordinating courier driver pick-ups and deliveries to and from external customers. The dispatcher uses machines to facilitate the communication between both couriers and customers.

Courier: or courier driver, are the people driving commercial vans or trucks loaded with various freight items, responsible for collecting and delivering parcels from external customers.

Customer: someone who is relying on the Freight Management System to transport their goods. There are two types of external customers, the recieving customer and the sending customer.

Internal Errors: These are driven internally from the organisation, e.g. miss labeling or over-landing of freight. Over-landing is the problem where freight arrives that is unaccounted for in the Freight Management System.

External Error: These are caused by customer misunderstandings. For example, the customer may underestimate the mass of the package or its weight, so that when a courier comes to load it, they may not enough capacity for it to be taken.

Clutching: a term used in mouse or trackpad interaction, where the user must lift the mouse or finger and reposition it in the center of the surface of the mouse pad or trackpad in order to navigate the cursor the extra distance required to successfully traverse a large display surface with a pointer.

Abbreviations

FMS	**F**reight **M**anagement **S**ystem
GIS	**G**eographical **I**nformation **S**ystem
GPS	**G**lobal **P**ositioning **S**ystem
NUI	**N**atural **U**ser **I**nterface
UCD	**U**ser **C**entered **D**esign
TCD	**T**ask **C**entered **D**esign
NDM	**N**aturalistic **D**ecision **M**odel
SA	**S**ituational **A**wareness
CE	**C**ognitive **E**ngineering

Chapter 1

Introduction

1.1 Problem Domain

This thesis is focused on developing interface technology that will improve operational practice in the freight logistics industry, specifically that of the dispatch operator. Dispatch operators, or dispatchers are required to oversee and manage the collection and distribution of domestic and international freight to ensure the packages correctly reach their destination. Generally, freight logistics is a large scale operation that requires a lot of management and oversight in order to ensure that the system operates effectively, efficiently, reliably and without loss to either the customer or to the business. Delays in transport can cause major costs to the company, hence it is crucial to the progress and cost effectiveness of the freight industry to identify potential problems early and take any precautionary measures to maintain operations effectively. There are several key players in freight management and courier operations that need to work together efficiently. This is to ensure that customer's needs are fulfilled with the delivery of goods and making a reasonable profit for the courier company, by consequence of the company making optimal use of available resources.

Dispatchers face a technical challenge of co-ordinating courier drivers, who perform the pickup and delivery tasks in the Freight Management System (FMS). The role of the dispatcher is to acknowledge a task or a set of tasks that need to be undertaken by the courier drivers and then issue commands to drivers to perform the operation. Enabling the dispatcher to do this efficiently means that the organisation as a whole can operate at a optimal capacity.

The dispatcher needs to know a set of information at any given moment, including:

1. Work that needs to be addressed immediately, for example new customer orders.

2. What work is currently logged and awaiting completion by the couriers.

3. What courier drivers are available and their capabilities in terms of capacity and traveled route.

4. What back up or contingencies are readily available in case of an event that disrupts the flow of normal operations.

Using this information, dispatchers are expected to co-ordinate and manage the human resources, the couriers in the field, to complete the pickup and delivery task work. Courier and freight handling organisations may potentially have a large set of fleet vehicles at their disposal, especially in heavily populated cities, or if the company operates over multiple cities. The courier drivers are adept at performing their specific duties in the field, but rely heavily on the management ability of the dispatcher to look ahead of the task work and assign it to them. The dispatcher assigns the delivery tasks while the driver is working, so they can focus on completing their list of delivery tasks, without having to return to the depot or distribution centres.

It is clear that to accomplish these tasks, dispatchers must have access to and process this critical set of information at any given time and must maintain an awareness of the overall logistics of the fleet at their disposal. Situational Awareness (SA) is required in order to co-ordinate tasking of drivers tactically, to accomplish the work in a cost and time-efficient manner. The effective organization and portrayal of this information to the dispatcher is crucial to the success of the courier dispatching operation. Indeed the overall design goal of the command and control system is to aid in the decision making process of the dispatcher. To do this the relevant information must be organised and presented in such a way to create a state of high SA, wherein the dispatcher understands all of the spatial and state information and is in an optimal state of understanding of the system. The dispatcher is then able to make a good decision based on this flow of information that makes use of the company's assets to meet the customers needs while minimizing the cost to the company.

In the dispatching application, the challenge for an interface designer is to not only design the delivery mechanisms (i.e presentation and interaction technology) for the set of courier and delivery information, but also how the informational content is organised and presented. Ideally this information should be delivered in a manner that enables a high bandwidth of communication to the dispatcher, engendering an accurate mental model of the real-time situation, that when assessed, provides the dispatcher an ability to make greater tactical decisions on-the-fly.

Typically, the role of the dispatcher in a freight organisation is to manage the resource pool of courier drivers, to enable them to perform their tasks efficiently and in a real time, cost effective manner. Dispatchers usually make decisions based on the available information, following a sequence such as:

1. The dispatcher gets notified of pick-up order by phone, email or internet and logs a manifest for the order.

2. The dispatcher selects a courier based on route and/or proximity to the pick-up location.

3. The dispatcher assesses the courier's state (for example if they have enough space or time remaining on their shift, traffic conditions etc) by contacting them by phone or via radio transmission (RT).

4. The dispatcher provides instructions to the courier on the pick up location and gives them the manifest order.

5. The dispatcher moves on to next task and waits for further contact by the courier driver if an issue arises.

The relationship between the courier drivers and dispatch operators is crucial to the pick up and delivery operations for a FMS. It is therefore very logical to try improve this relationship where possible with technology, in order to enhance the connection between the dispatcher and courier driver.

1.2 Research Purpose and Rationale

The research reported in this thesis is an investigation of how to provide a better computer interface to support the dispatch operator in the courier and freight logistics industry: the objective is to assist the dispatch operator, with state-of-the-art tools that enhance Situational Awareness (SA) and enabling efficient decision making. The underlying premise of this research is that building interfaces that communicates good SA, will in turn lead to better decision making, reduces operational costs (due to fewer errors) and have a significant impact on the customer satisfaction for both senders and receivers. In this regard, there is an obvious need for a command and control system that enables users to maintain awareness and control of situations that are considered to be critical, especially when it involves the management of people and their individual tasks.

There are two aspects of this research: the information delivery function and the interaction function. The information delivery function is the method in which the necessary information is provided visually to the dispatcher through the use of computers and displays. The interaction function is how the dispatcher uses this information, changes it, or interacts with it in some way that changes the state of the system. The more obvious solution for the information delivery function is to increase the display Field-of-View (FOV) (e.g. larger or multiple monitor screens) so as to spread-out and enable organisation and clustering of related information. While this display approach may be a good solution, it precipitates the question of how do you interact with 'spread-out' information across multiple displays?

Using a baseline of traditional dispatcher workstation of monitors, mouse and keyboard, this research entails the use of Wide FOV display systems with alternative input devices including touch and gesture interaction. It will also compare the differences between using multiple screens in a variety of arrangements, i.e. vertical stacking of monitors vs horizontal configurations. By comparing these methods, a suitable work station or terminal can be designed that allows the operator to have excellent control and optimal situational awareness. Although a comprehensive research activity would involve both the interface technology and organisation of content, the specific goal of this research is to concentrate on the delivery and interaction technology. This is to determine if using Natural User Interface techniques can perform better as alternative interaction methods beyond the use of keyboard and mouse devices.

In conducting this type of research, it is important to ensure that the technology developed can fit within the context of existing work practices, that the user interaction comes naturally and consequently of high bandwidth. To achieve this, the author will apply two methods of Interaction Design known as User Centric and Task Centric Design (UCD and TCD) [1][2] in an effort to completely understand the problem domain. This design approach will guide the research and the design process to create a suitable prototype using re-iterative development techniques to produce a quality interface. The outcome will optimize the application of NUI technologies for courier dispatch and by creating better job satisfaction, reduce cognitive workload and facilitate rapid and effective decision making. In the process of reaching for this goal the author's research explored a variety of emergent NUI technologies in an effort to discover task efficient information navigation within the command and control domain of courier dispatching.

1.3 Thesis Summary

This thesis is presented in the following manner:

Chapter 1: Introduction.
Introduces the functional tasks and challenges involved in courier dispatching and provided a justification for re-designing existing dispatchers interfaces.

Chapter 2: Background Research.
Provides a review of the relevant literature, identifying existing applications of command and control systems in other critical industries such as Emergency Medical Dispatch, as well as the review of interface technologies that could be beneficial for the User Interface (UI). The Chapter includes a review of robust methods for assessing the goodness of control and display configurations.

Chapter 3: Design Methodology.
Discusses the interface design task and acknowledges the relevant stakeholders. The design task focuses on dispatchers' tasks broadly while acknowledging the influence that the other stakeholders have in the system.

Chapter 4: Prototype Development.
Describes the design process and development for the prototype dispatch workstation, complete with multi-monitor screen configuration and NUI hardware tools to be evaluated.

Chapter 5: Evaluation.
Presents the experimental design for the evaluation of the prototype.

Chapter 6: Results.
Presents the statistical results of the prototype experiment and discuses the implications of the research.

Chapter 7: Conclusion.
Provides a conclusion on the current research and presents further research for future investigation of NUI technology in dispatcher work stations.

Chapter 2

Background Research

2.1 Background Research

When considering command and control interfaces within the context of courier resource management and the FMS, it is worth investigating alternative solutions to other occupational areas that also require a higher level of cognitive processes with information processing and mental demand. This is necessary as there is a rich set of research in command and control interfaces in other occupations that may translate into courier and freight management practises. For example, in emergency dispatch operations such as police, fire or ambulance or alternatively in mission critial scenarios found in Air Traffic Control (ATC). All of these systems demand on-the-spot accurate planning and decision making. In ATC, the decision-making process is crucial to aviation safety and efficiency as Hopkin [3] discovered. The decision making is dynamic based on both uncertain and scheduled events that occur frequently. Decisions are often time constrained and based on uncertain information however they are often relied upon for the safety and well being of many peoples lives [4]. In these scenarios, all dispatchers must maintain an extremely low fault tolerance, while providing a reliable response mechanism to handle any potential systematic anomalies. For example if a vehicle breaks down, the operation must continue to according to schedule to ensure the safety and satisfaction of everyone involved, so the dispatcher must respond to this event appropriately to sustain the business. This requires the dispatcher to maintain a high degree of SA and co-ordination ability [3]. Although the various dispatching occupations have different problem domains and cognitive overheads, they do share similar processes that operators must follow which can require a substancial amount of mental load. For an interface designer, it is important to acknowledge these aspects when designing for a user with a specific task or outcomes that are safety related or for task that require a

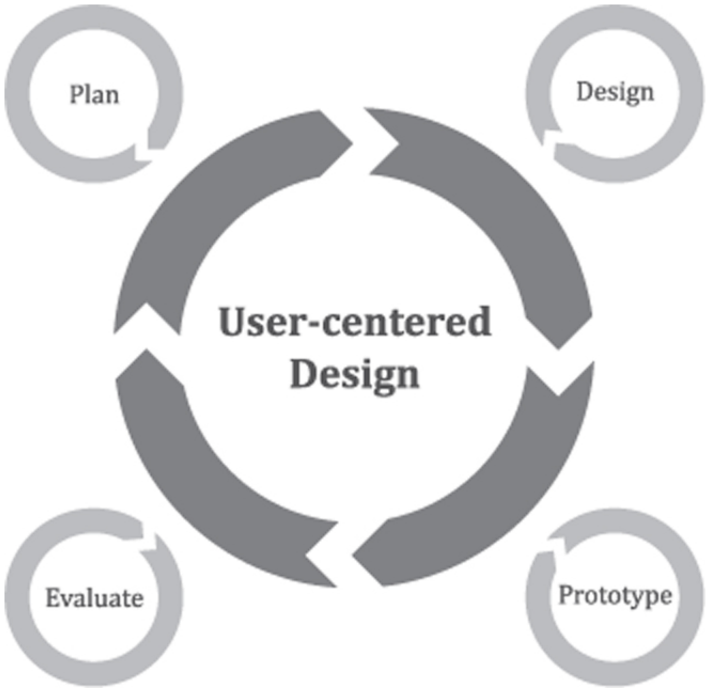

Figure 2.1: The Re-iterative work flow model of User Centered Design

critical level of precedence for their problem domain. Kaempt and Orasanu state that to be effective, decision-support and decision-training systems must be tailored to the cognitive processes naturally invoked by the decision maker [5]. As a part of the interface design, interaction design principles known as User-Centered Design (UCD) (Figure 2.1) and Task-Centered Design (TCD) are used as methods, in which elements for the design strategy for the prototype are taken from these two design methodologies. These includes the following steps below:

1. Understand the target user with probing and thorough background research.
2. Define the Interaction Process for the users with use cases.
3. Design the UI and develop a prototype for evaluation based on user research and use cases.
4. Iterate over a selected prototype model and validate it against the initial requirements.

By adopting the TCD methodology, a deeper understanding of the courier dispatcher taskwork and how the tasks fits in with the existing system will emerge. This understanding cannot be obtained from a set of abstract specifications and must be acquired using techniques such as observational studies and expert level user interviews. The extent of this methodology also requires the designer to analyse existing examples of interface design for similar occupations. In addition, the TCD and UCD design methodologies also allow for iterative development, which is essential in producing an ideal interface design.

The challenges for this interface design task are as follows:

1. To thoroughly understand the problem domain, the occupation and any tasks that are undertaken by the user.

2. Ensure that the system developed caters for the specific goals of the user and assists in optimizing the completion of taskwork.

3. Minimize the learning time required of the dispatcher while maintaining an acceptable level of system functionality.

2.1.1 Examples of Command and Control Dispatch Systems

FIGURE 2.2: A typical emergency medical dispatch environment

By acknowledging current examples of command and control systems, low-level control, display decisions and interaction paradigms can be translated when creating a solution for a problem domain that shares similar human requirements. Existing command and control systems such as Emergency Medical Dispatch (EMD) have shown that there are generally a set rules to follow when making on the spot critical decisions. Analysis of what makes these decisions complex, creates a benchmark about the systems in place and how future systems could be developed based on these systems by software and hardware engineers [6]. For example, in EMD, lower level tasks such as resource monitoring are often interrupted with incidents that demand a higher level of attention, meanwhile the routine work must also be completed, but may be put in the background while the demanding task is handled [4]. Under this set of conditions, operators exhibit contrasting levels of Situational Awareness for the various incidents that occur [3]. In research undertaken by Blandford and Wong [4]'s, a qualitative technique is developed to gather information about decisions made in emergent operations. These decisions are identified and developed into a Critical Decision Method (CMD) interview scheme, which was used to identify common themes and decision strategies that were made by EMD operators. By doing this they were able to identify the specific tasks and processes dispatchers followed and which of these tasks were more complex than others.

2.1.1.1 Emergency Services

Figure 2.3: An emergency dispatcher in his environment

Emergency service dispatchers ensure that any danger, potential threat or life critical event that occurs is responded to quickly, with the optimal human resource and equipment that is needed to handle the job. Typically the most important information shared by emergency dispatchers is the location of an incident and the circumstances surrounding the incident as that event is taking place [7]. The next most vital piece of information is locating the resources and determining their status or availability to handle the situation. This information flow is fairly similar to that of courier dispatching management, in the fact that they both use critical and sometimes incomplete information. This information may be dynamically updated as the situation changes, to ensure the task is handled effectively and efficiently.

2.1.1.2 Air Traffic Control

ATC is a complex task which relies upon real time data acquisition and decision making by the Air Traffic Control Specialists (ATCS) [3], who in part manage the safe execution of take-off and landing for airplain traffic at airports. The ATCS decision making process is crucial to aviation safety and efficiency [8]. The decision making process involves many factors such as constantly updating relevant information and resolving conflicting goals. ATCS often make difficult decisions with incomplete information, under time pressure and high workload. Despite all these factors, the number of operational errors remains relatively low demonstrating the synergy of technology and the skill of the ATCS [8].

2.1.2 Situational Awareness: The Psychology behind dispatching

SA refers to the awareness that an individual has of a given situation. SA is formally defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future," [9]. In most command and control environments, SA is one of the most crucial elements required to complete the necessary decision making tasks for dispatching. However, mentally maintaining an on-going model of a complex situation can create a large amount of cognitive overhead for a dispatcher. This level of mental cognition can be challenging but can be made easier using assistive technologies like computer systems, to present information visually in a way that enables the operator the ability to create a symbolic model of the given environment. By doing this, it reduces the amount of cognitive load placed on the dispatch operator [10] so they can then understand the operation without having to mentally keep track of all of the intrinsic information. Furthermore, dispatchers can invoke specific information about the problem domain almost instantly, which greatly benefits their ability to learn and manage an accurate mental model. Wong [11] stated that SA is an important part of decision making in dynamic environments and that decision makers are said to be more situationally aware, if they have an up to date model of the situation. By being more aware of the situation, dispatchers are in a better mental position to make decisions and orchestrate a set of actions about the current situation. In doing this, professionals create an internal Naturalistic

Decision Model (NDM) [6] for when the same or similar situation arises again, through their learned behaviour they can automatically perform a proven set of interventions necessary to complete the operation and succeed at their role. This enables dispatchers to address problems that arise swiftly with a minimal rate of failure.

2.1.2.1 Making Decisions in Time-Critical Situations

For command and control operators to make good tactical decisions, they need to take in as much information about the situation as possible. ATCS are often faced with time-pressured situations, where they must make their decisions based on many factors, such as constantly updating relevant information and resolving conflicting goals [3]. The information must be reliable for the current decision so as not to force an error on the dispatch operators ability to make and accurate judgement or task to handle a specific task. It is therefore essential that computer systems are designed to provide accurate and plentiful information to the Dispatcher for it to be effective. Wickens [10] recommends that future automation and computer aided technologies should focus their efforts on the development of decision making aids for ATCS.

It can be seen in EMD that common processes are established that dispatchers can follow in order to make the best decision about a given situation. These processes are identified by Wong and Blandford [6] and have reasonably well defined paths to follow on how to correctly handle a given situation. By doing this, it makes the job easier for the dispatcher to efficiently establish the best approach to the situation, (i.e. release an ambulance, a helicopter etc.) However this method is still highly reliant on the reliable flow information, as the caller who is communicating with the dispatcher may start releasing additional information as time elapses and therefore may cause a significant change in how the situation is handled by the dispatcher and their response team. In the courier dispatcher case, situational changes rarely happen at the customer end and are more likely to be generated by a courier driver; for example, a courier driver may suffer mechanical problem during operation, that could not have been predicted by the dispatcher. Situations like this rely on creating a back-up plan to follow, in order to make the best decision when such a situation occurs again. Furniss and Blandford [12] states that EMD is typically a team activity much like courier dispatching, requiring fluid co-ordination and communication between team members. These working conditions are best represented by a Distributed Cognition Model, which can be seen as the operation running as a whole.

2.1.3 Technology in time-critical scenarios and reducing operation costs

As asserted by Crowcroft [13], technology provides solutions to for many courier processes and problems including, ameliorating ecological reasons enhancing an existing methods of operation, to make it safe and prevent damage, or to make it more efficient and economic [14]. Large operational costs in excess of US$500 Billion are spent on courier logistics, where most companies are running fleets of at least 25 vehicles as Garca-Ortiz et al. [15] discovered. As operational costs begin to increase due to rising petrol prices, companies must look at better methods to reduce their operational costs. Time management and situational awareness become key aspects to dispatch operators when wanting to create a highly optimized organisational system. Several technologies are available that can assist the ability of the Dispatchers to perform better and increase their ability to maintain the workload. These include technology solutions such as automation technologies, visual information presentation systems, digital maps and geographic information systems, live point to point communication, video conferencing, display technology, or human computer interaction technologies such as multi-touch touchscreens and hand or body gesture interaction or another form of advanced human interaction. There are many more opportunities for technology to assist in this industry, which is what makes courier and freight management interesting to investigate.

2.1.3.1 Geographic Information Systems

GIS Systems have been shown to be beneficial for emergency systems as part of the dispatch operator technology [16], [7]. GIS also has played an important part in the enhancement of logistics and freight management by enabling workers in the industry to connect with each other in real-time and enabling customers to monitor the location of their goods in transit [14], [13]. GIS and computer graphics simulations allow for information to be superimposed over a topological map, where users can gain a greater understanding of an area, or to be able to understand statistical data or other important information. This is valuable to many command and control scenarios but especially in the case of courier logistics, where the information about freight pick up locations or a courier's position, can be easily displayed on a digital map [15]. This would give a dispatcher a much greater understanding of the situation and thus increasing their SA. GIS can also benefit from NUI technology and be manipulated using touch and gestures, which is now quickly becoming a standardised mode of interaction for spatial navigation [17], as the NUI technology enables a richer interaction ability with gestures and proximity etc.

2.1.3.2 Real-Time Data Acquisition

The ability to gain information about the current situation is incredibly essential to the success of the dispatcher [15] as it enables them to make effective decisions. This is what enables an FMS to run smoothly. Mobile data technology can provide internet access and therefore the ability to provide live status information, becomes increasingly important for the management and tracking of couriers and freight for dispatchers and also for customers. This rich information can assist with vehicle location, the ability to provide digital signed deliveries, as well as job completion statuses which can attribute to greater task efficiency within the while logistical operation [14]. The bottom line is that real-time information benefit enables operational overseers such as dispatchers to make better impromptu decisions, as well as respond to customers with information about their deliveries.

2.1.3.3 Display Technology and Representing Information Visually

FIGURE 2.4: A dispatcher workstation using a wide FOV array of monitors

Display technology provides the electronic representation of computer data and is a fairly essential for the dispatcher to complete their taskwork. Computer displays provide spatial and state information to be interpreted by the dispatcher in order for them to can create a mental model of the situation. Without this, they would be required to perform their duties using large paper based maps, where they cannot mark the surface permanently, making it difficult to manage courier drivers and their tasks in a real-time manner. This is why it is important to acknowledge the value that computing and display technology can afford. With current graphics card technology it is possible to attach many different monitors to a single computer. By doing this, it increases the ability for one person to receive a greater bandwidth of information from a single computer, in a way that is non-disruptive to the users flow and ultimately has more operational power at their disposal [18].

Through this use of multiple monitor configurations and high resolution displays, effective screen area can be provided to dispatchers. One must be careful in managing the use of the display area. Much like a cluttered desk, poor organisation and delivery of information can cause mode blindness effects when obscuring information on a display. Mode blindness is a psychological problem where a person is unable to identify the usage of whats in front of them usually due to an overload of information, forcing them to take longer delays in processing time. This means if the information is not presented in a way that is intuitive to the dispatcher or specialist, then that display does not communicate said information with a high bandwidth to the brain and can instill additional unwanted cognitive overload to the operator[19]. It is important to consider information organisation and portrayal when designing the software architecture of a dispatch interface, as the information needs to be handled and presented in an intuitive manner[18]. Just as a cluttered desk can cause issues with distractions not to mention difficulties with locating objects, poor information representation is also distracting as if its not in the right place when its needed as the time taken to locate the information may result in the operator forgetting information. This is usually due to the loss in focus when trying to locate the missing information. These effects could be handled by providing a larger or additional displays, however simply providing more display area isn't a clean solution. Navigation issues arise with ultra wide FOV display systems, where using a mouse alone to interact with the wide display becomes fatiguing and induces excessive mouse clutching [20]. Solutions to this are making the mouse have a secondary pointer, located on a different display so that the user may switch between the two cursors, enabling the user to quickly interact with data in two separate displays [20].

Since information is the dispatchers main source of knowledge, it is important to consider how this information is organised and portrayed to them. The panel on human factors in ATC suggest that decision making may be improved by displays that are organised to represent strategies that work in the real world environment [10].

2.1.4 Natural User Interface Technology

Natural User Interfaces (NUIs) are computer interfaces that are specifically designed for a certain style of human interaction and are sometimes considered to be more natural for human user operation than traditional computer input methods. They are designed make the learning curve for users to be as short as possible [21]. The term NUI encapsulates any technology item that allows users to interact in a more natural or humanistic way with computer systems. Input techniques such as touch-less pointing, direct touch, hand and finger swipe gestures, body pose and skeletal recognition or voice command recognition, are all considered to be Natural User Interfaces [17].

However if the interfaces are more natural, they may not actually be more efficient or less cumbersome [22]. These efficiency constraints can be a result of latency in the emergent technology, or systematic flaws in the software design. It is also necessary to match the style of interaction towards the task itself, so that performing the task becomes more natural and easier to pick up for someone who has not used many computer systems before and have not had the time to develop skill with devices such as the mouse and keyboard.

One of the earliest forms of NUI is the touch screen system and this has redefined how users interact with computer systems, most notably in embedded or mobile systems. However, touch interaction is still be considered to be in its infancy and sometimes far from natural when used in a real world scenario [22]. For instance, different methods of touch based input in terms of a monitor overlay have been invented that are able to detect multiple points of contact accurately and which translate into mouse actions. This has a very distinct nature of interaction as the user may touch the screen in an intuitive manner, but yet the input mechanism is still not as efficient as a physical click or a keyboard shortcut. It may be this fact that makes the touch screen less usable as an input mechanism for a repetitive task as if the input mechanism is too clunky or difficult to operate thereby creating interaction problems which break the users work flow. However, this can also be an issue with the software and system design, as a touch screen is much different than a mouse (direct vs indirect interaction), so the way in which the computer system is can also be very different.

If a NUI system cannot cope with the intense nature of the workload, it will be unable to perform and do what the user commands. Then it will cause a negative reaction towards the system which will most likely prevent the user from using the system in its intended way Villaroman et al. [21]. This is a common problem in user interface design and is what prevents new technology from taking off, therefore it is essential that the technology is exposed in such a way that is receptive to the user and enables them rather than disables. By acknowledging this and using the task centered design, we can ensure that the interface and the software system developed is able to support the task requirements of the occupation.

Many mobile and embedded devices have made excellent use of touch screen technology [21], for instance in mobile phones and mobile computing, it has enabled the size of the display to take up the majority of the devices physical size, without having to provide external buttons for user interaction. This has benefitted the mobile device industry dramatically as it requires less moving parts and also enables a greater screen real estate, promoting longevity with devices as well as greater visual presentation of information.

Touch screen technology poses a good future and is in high demand for most mobile smart phone, tablet devices and also merging into desktop and laptop systems. However it is not without its inherent flaws which need to be acknowledged, if the technology is to be used in commonplace. For example; use of large touch screens over a long duration, requires users to hold their arms at approximately 90 degrees to the body causing undesirable fatigue [23]. This effect must be acknowledged when building a system using large touch surface, as for the technology to excel in a working environment, it needs to be completely supportive of human ability without usage constraints. Much like when introducing a new software system, it must be robust enough to handle large amounts of traffic and data throughput and the physical interface must handle frequent usage without breaking the users workflow or causing complication[22]. This is highly relevant when considering occupations where repetitive use over long periods of time are likely, so the system must not be fatiguing in any way to the operator. Due to these facts, it is highly important to create a system with a good degree of both software and hardware engineering, to create a total system to be effective. The software interface needs to be implemented in such a way that it is both controlable and understandable by the operator, without creating unnecessary cognitive overhead [18].

2.1.4.1 Touchless Interaction Systems

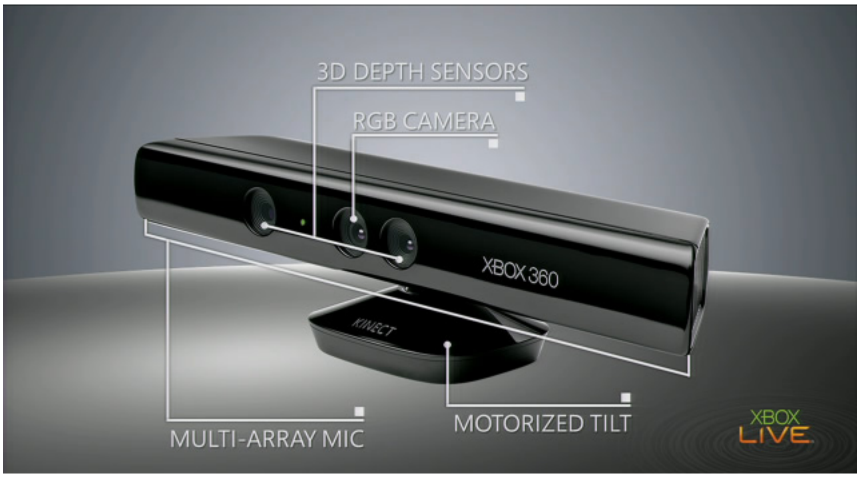

FIGURE 2.5: The Microsoft Kinect depth sensing camera system

Touchless NUI systems are emerging systems that do not provide any physical interface for the users, but provide control by tracking body-parts and learned features. Skeleton and hand tracking control is possible with such devices as the LEAP Motion controller or Microsoft Kinect [24], giving users an computer input that doesnt require any physical interaction, but to make gestures or interactions in the open air. Systems such as these use stereoscopic cameras which enable depth sensing. It is with this ability that gives users three dimensional control as computer input. This would be particularly useful if the user was un-able to touch the screen from being too far away from the monitor, as this is often the case in large display systems or in theatre style systems. There are obvious eye and other health risks to people that may arise from being positioned so close to a display over a long duration of time, so it would be beneficial to utilize a system which can detect input without having to physically touch the screen.

The repertoire of touchless interaction can encompass finger, hand, body or head tracking and pose recognition. The systems are usually implemented by using digital camera hardware system paired with software that takes the data from the camera and processes it using computer vision algorithms to find information of interest such as pose, shape, colour or depth [24]. Also since these types of interface system tend to not rely on a physical input, they can potentially track a large number of objects at any given time. This is what makes touch and touch-less systems Natural and many research centers are creating new and intuitive gestures to support these methods of interaction.

Gaze and head tracking can also provide users extra control functionality, as it enables the user to look at targets or spaces on the display in order to select or interact with objects in the space. This could provide benefit for larger displays as it would make it quicker to select objects than by navigating a cursor in traditional object selection methods.

A phenomenon that has emerged from NUI systems is the notion of performing gestures to provide specific input control for users [25]. This gives users the ability to create different patterns, that a computer system can learn and then perform a certain action or command, based on the execution of the learnt gesture. It is necessary when creating these learnt gestures, that the input is intuitive to the user, so they can feel confident in when they perform the gesture, that the command they wish to execute is going to occur. Gesture recognition can be found in technologies such as touch screens, track pads, or in Touch-less Interaction systems. It is becoming increasingly more commonplace in every day computing, as methods like pinch to zoom or draw a circle to scroll through a document are being adopted as replacement or compound methods of interaction.

2.1.4.2 Voice Interaction

Another natural mode of human computer interaction is speech communication with computers. As human beings are capable of speech and verbal communication; a natural form of communicating in person to person interaction, it would be useful for people to be able to communicate with machines with spoken language rather than using a keyboard for data entry or for issueing commands. The users natural speech and dialogue would be used to issue commands to the machine in order for the computer to perform a particular task. However use of such technology would be more beneficial when paired with another NUI technique in order to be fully effective [24].

2.1.5 Methods of Analysis

With the myriad of interface technologies described above and the diversity of applications in which these technologies can be applied, the pervasive question is: how can we measure the goodness or efficacy of various control/display considerations? Accordingly, there are many methods for analysing interfaces in terms of their goodness, or usability.

Objective measures of goodness typically draw upon psycho physical principles, such a response time and accuracy in performing a particular task. Such an approach requires careful design of experimental conditions to control the variability inherent in human experimentation. In the case of assessing the goodness of NUI when pointing or designation is required, often Fitts's Law is used [26]. Fitt's Law is a well studied experimental paradigm wherein the channel capacity of the human machine interface is estimated using a tapping task where the separation and sizes of the targets are manipulated.

The analysis of the tapping data provides a measure of the influence of preprocessing or reaction to a particular point task as well as the impact of motor response as a function of the distances involved in tapping [27], [28].

Another psycho-physical metric for goodness is determining the intuitiveness of an interface. Generally, intuitiveness can be measured as the slope of the learning curve. With repeated trails, what is the rate at which performance improves (in reaction time and accuracy) and begins to asymptote. The more intuitive interfaces have the greater slopes or steeper learning curves.

Subjective measures can also be used to assess the goodness of an interface. Traditional questionnaires or interviews can supplement the findings using the objective measures. Usability testing is another approach that is a hybrid of the objective and subjective metrics. The idea of usability testing is to have subject users perform real world tasks using the interface while being observed or video recorded by the experimenter. The subject is often asked to think aloud, expressing what is going through their mind as they are trying to perform a task with a control/display interface. The downside of this usability approach is that it is inherently time consuming, requires a considerable amount of data extraction time and often does not support rigorous statistical analysis that accompanies the psycho-physical methods.

2.2 Background Summary

Command and control style computer systems can be mentally demanding work environments. To excel in these environments, the dispatchers must have a good understanding of the problem domain and maintain an accurate mental model of the system to ensure the operation performs as expected. The operators must have a great amount of SA to be able to make effective and impromptu critical decisions in order to perform their tasks well. There are a large selection of technology options available to assist with performance and task handling. In order to provide sufficient information about the taskwork, providing a wide FOV display system is very useful in terms of being able to present quality information but also allows for essential programs to be run simultaneously without having to switch task windows. However there can be difficulties with navigating the large FOV displays. The provision of NUI to the system can potentially allow for increased task efficiency. By enabling direct touch and voice technologies in the command and control interaction for the dispatcher, they are afforded a greater bandwidth of command and control ability.

As the technology of command and control systems is evolving rapidly, the challenge is to configure the best control and display hardware and software components that: 1) can organize the information, 2) portray the information, and 3) allow interaction with the information, so as to enable 4) building dynamic mental models so that the dispatchers can make effective and timely decisions. The keys to this optimization will be the application of research methods to assess the goodness of candidate configurations.

Chapter 3

Design Methodology

3.1 Research Approach

The main focus of this Masters thesis is to investigate and compare methods of user interaction for task efficiency for use in freight management and similar applications. As there are many approaches to computer interaction it would be beneficial to investigate which are better at performing pointing and selection based tasks across a set of wide FOV displays. While this is not the only method of computer interaction used by a dispatcher, pointing is frequently used to issue instructions and interact with the computer user interface. Effective pointing and selection is necessary to help dispatchers navigate through a large amount of task specific information in a way that does not distract or prevent them from remaining focused. Generally, dispatchers of any kind need to have a high bandwidth of real-time information flow to build a mental model about the problem domain. As computers are highly capable of providing the underlying computational cycles for command and control, the focus of attention for interface designers should be directed at optimal methods for information display and interactions with that display. One of these methods must be aimed at effective navigation within the information space provided by the display.

3.1.1 Research Questions

Within the context of a command and control system for dispatchers in a freight management, it can be assumed that a large format display system will be needed. The configuration of this display will be discussed in subsequent sections. Given such a large area display or tiling of multiple displays, two key research questions emerge:

What User Interface Interaction method is best used for pointer navigation over a wide FOV Display?
and
What style or mode of interaction is best for command and control tasks?

3.1.2 Prototype

In order to address the research questions outlined above, A prototype system was developed that combines a wide FOV display system with NUI technology. To do this we followed a standard interaction design process as detailed in the next section.

3.1.3 The Use of Interaction Design

User centered Interaction Design following an iterative process of determining user needs, designing technology to meet those needs, and then evaluating the design. As a first step in this process, the user environment and their tools must be identified to get a better understanding of the workplace tasks and environment. There are several effective techniques for deriving this useful user data and care must also be taken to obtain this data without disrupting the workflow of the user. Wong and Blandford [6] use an observational study technique to find information about how EMD crews and dispatchers performed their tasks and in so doing identified processes that dispatchers take to maintain and complete their task work. By applying this technique to the courier industry, we can find useful information about the dispatcher' workflow, how they get the work completed, how they split the tasks between the workers, the types of technologies they use and other useful information related to the occupation. In addition to observational studies, expert user interviews can be used to gain greater insight into the task work and what factors effect the dispatcher and other workers in the freight and courier management occupation.

3.2 User & Task Analysis

To provide vital information about the dispatcher, the processes they follow and the systems they use, study of the user in their natural working environment is needed to identify the processes and tasks that are executed. By doing this, important aspects can be identified about the systems and processes in place that we wish to enhance. It is crucial to the design process that we have complete understanding of the user and identify their needs and difficulties when performing their task, prior to and during the prototype design. This is so that during the design phase of the prototype, the user and task is identified to guide the development. In this design process, we will identify the stakeholders in this system in order to make informative design decisions for the prototype interface.

3.2.1 Observational Study

An observational study was performed at local freight and shipping depots that were local to Christchurch, New Zealand. similarly to Wong and Blandford [6], where experts were monitored during their daily taskwork and asked questions after a significant event was handled. The study aimed to do the following: 1. Identify important systematic business processes and other aspects vital to the overall operation and 2. Identify the work that is being carried out by the dispatcher who is tasked with responding to and monitoring the operation. From this information more educated decisions can be made about the way the prototype should be designed.

3.2.2 Expert Interviews

Three professional dispatchers, currently operating in the freight industry were interviewed as part of the design process. The dispatchers were asked questions about the task work they were expected to complete, the technology they are using to do this, what the current issues are in the management of freight and finally potential methods of improving their current systems. By doing this, we are identifying potential issues early on in the design process, and ensuring that the people who are using the system have had significant input into the design of the interface, which should result in a better system. This will help ensure that what we are delivering is something that the end user will appreciate and will want to use.

3.3 Lessons learned from User and Task Analysis

Here we discuss the information gathered during field research while uncovering information about the Dispatch Operator as well as the other stakeholders in the system.

3.3.1 Observational Study Report

An observational study was undertaken at a local freight company Roadstar Christchurch. This particular company dispatched couriers to an area that spanned a large coverage area, which included other towns and cities other than its own. It also has to communicate with other hubs in its chain such as branches in Dunedin and in Invercargill. This particular freight depot specialised in carrying palletised freight. This is where the freight is loaded onto pallets about 1 by 1.2 meter area and bound by being wrapped in a thin PVC 'cling film' type of plastic designed to cling to itself and provide a tight bond around the goods to protect them. Larger Items may be carried on multiple pallets, enough to cover the floor area of the trucks. The pallets were then loaded onto delivery trucks to be transported to their various destinations. The company also handled bulk delivery items where necessary in order to make good use of resources, instead of having idle drivers. The dispatcher does not have to perform the wrapping, loading or transporting, however they need to understand the process in which the task is handled so as to maintain their awareness of what is happening internally with the operation. Typical phone calls lasted less than a minute for order processing, otherwise they could take longer if the call was regarding an internal or externally driven error. Other technologies were RT and mobile communications, as well as a computer terminal running various softwares such as an email client, a proprietary freight management software and a digital map to track drivers and locate delivery and pick up points (figure 3.1).

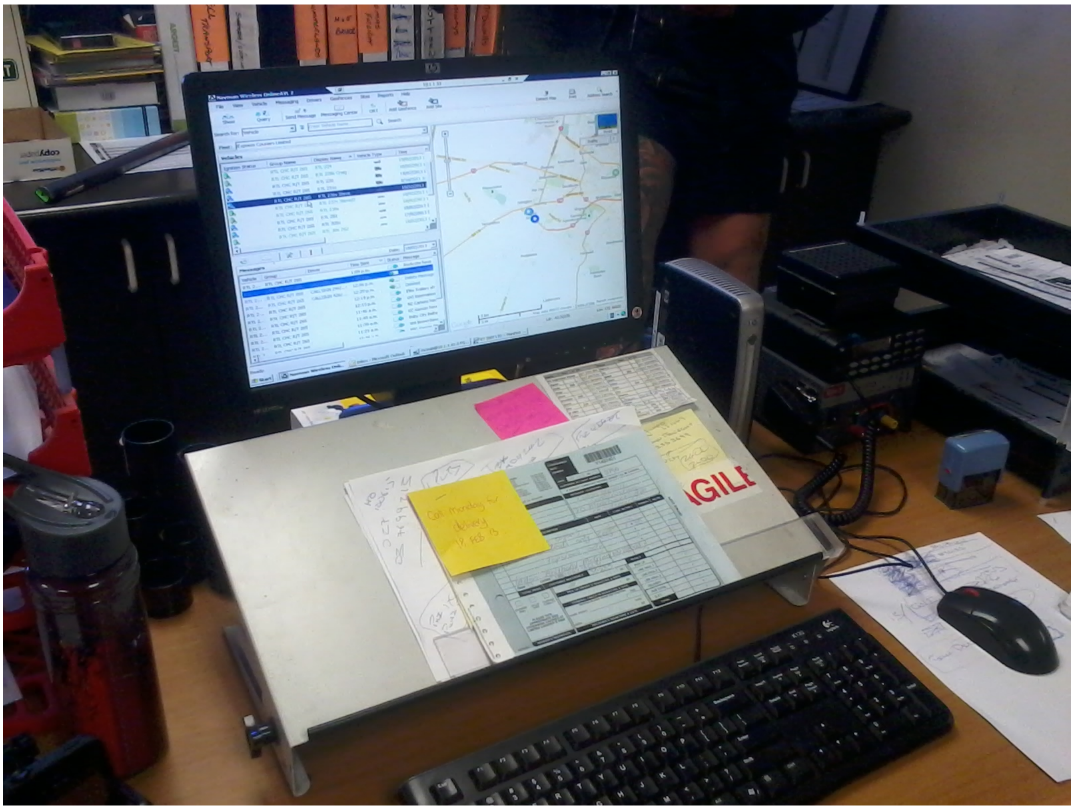

Figure 3.1: A typical dispatchers workstation.

In this observational study, Three dispatchers were observed while performing their dispatching duties.

There were three observed methods of creating a job order:

1. Customer telephone call the freight company and verbally request a pick up.
2. Customer emails or faxes the freight company and requests a pick up.
3. Customer uses a web base client to place the order see figure: 3.2 below.

The first of the two order types requires the dispatcher to perform manual data entry the third item removes this requirement. This is in the form of a consignment notice or a manifests. If the customer has been previously handled by the company, their details are usually logged in the system for future courier pickup requests. Of the three ordering styles the telephone method can be thought of as an interrupt and generally commits the dispatcher respond to the call immediately, dropping their current activity and process the pickup request. This form is considered to be more urgent than the other methods, as it requires the direct attention of the dispatcher.

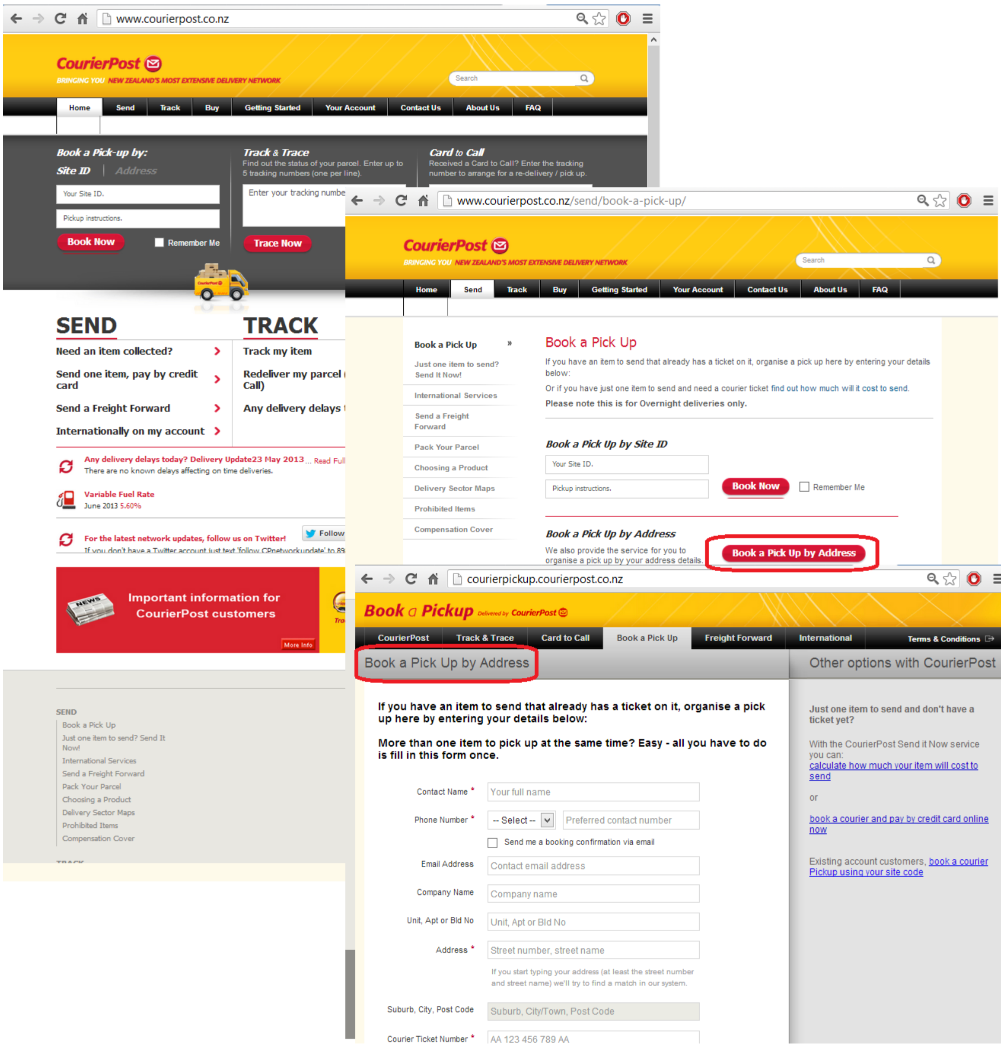

FIGURE 3.2: A Typical web interface for customers

3.3.2 Expert User Interview Report

After the observational study was complete, the dispatchers were asked if they were available to provide greater detail about their duties, as well as information about the occupation itself, where the flaws are and what they think could be improved. Also after taking a pickup request, they were asked about the procedure for completing the work. A rich source of information was provided from the experts into how the business operates, what the internal and external customer interactions are and the practises that take place when certain things do not go as expected.

The dispatchers found they were often correcting faults driven internally and externally to their system. External customers were not often in a position to accurately judge or gauge the freight itself, but merely state whether it is available to pick up and a very rough estimate of its size, shape or weight. It was this lack of customer understanding that can cause negative effects on the system. For example, the customer may inaccurately judge the size of their load, making the dispatcher send an inadequately sized courier to transport their goods, when in fact they actually need a larger truck, or vice versa. This causes the dispatcher to unknowningly force errors into the system and its processes, by not providing the optimal resources to do the job. It is important that dispatchers have a great understanding about how external customers function in the system and how they can cater for and strategize around it. These errors will not be caught until the driver arrives at the scene to load the freight. In any case the courier will either abandon the freight and tell the dispatcher to send a new driver, or take part of the load if they are able. Either way, this is a non-profitable expenditure and should be avoided if at all possible.

Another type of error in the system is over-landed freight which is caused internally. This is freight that is un-accountable for and is in the depot awaiting some action to get it to where it needs to be. This can happen by means of the loader not correctly filling out the consignment note or simply when the documentation attached to the freight becomes missing during transit. All of these system anomalies must be corrected and it is usually up to the dispatcher to make the decisions and perform the corrective measures to handle the situation and ensure the freight is delivered to the correct customer, at all costs. Sometimes dispatchers may have to organise special one-off deliveries, to correct miss-placed or over-landed freight, which can be a very costly outcome.

3.4 Stakeholders

While the focus of this research is the dispatcher, it is necessary to identify and consider the other stakeholders who are involved. By identifying the people involved in the system and what they are to expect out of the service, a more knowledgeable decision about how to best facilitate this service can be made during the design process. With this information in mind, A task specific system can be designed to facilitate the situational awareness and task efficiency requirements of the dispatcher. As a result of this process the system developed should maximise the job satisfaction for dispatchers, increase efficiency goals for the business and also improve customer satisfaction.

There are several key stakeholders in the courier industry, but the primary concern for this research are the people relied upon for maintaining the first point of contact with the customers and with the drivers themselves.

The people identified as key stakeholders are:

1. **Dispatch operators.**
2. **Courier drivers.**
3. **Customers.**

Each of the stakeholders are discussed below.

3.4.1 Dispatch operators

Dispatch operators or dispatchers, are employed to: 1. Monitor the requested pickup and delivery (and possible storage) of the various freight items; 2. Assign specific courier drivers to transport those items to and from various locations; and 3. Keep an overview of and manage the internal operations of the courier and freight management system. Dispatchers typically have gained significant geographical knowledge of the routes and areas. Often dispatchers are former courier drivers themselves who have learnt the operational area and delivery routes well with significant topographic knowledge. The dispatchers generally try to maintain a good working relationship with the courier drivers and get to know them personally through the close nature of the team based work. The dispatchers are generally situated in the Freight depots where the packages get sorted or can be positioned at a command center, where they can co-ordinate and work with the courier drivers and other stakeholders more effectively. The dispatcher typically sit behind a desk and monitor the operations from their work station. There are many different approaches to a dispatchers work station and the interface design of the computer system and technology. This can range from fixed range Radio Transmitter (RT) communications systems, to cell phones and landline phones for longer distances, GPS tracking systems and other computer enhanced software systems for tracking fleet vehicles or for customer interactions to assist the Dispatcher in maintaining their task work There is often a myriad of pen and paper notes and other documentation, but the taskwork generally stays the same between each style of dispatch interface.

Requirements: Dispatchers are expected to make many decisions about maintaining the work flow of the organisation, organising pick-up and delivery tasks with external customers and also contacts courier delivery drivers, usually based on what route the driver is travelling on and/or which driver is in a better position to be assigned with the job. They also are required to assign freight awaiting delivery to the courier drivers prior to when their shift begins. All the while dispatchers are required to have great knowledge of the geographical area as it is essential to know the location and layout of job sites, traffic patterns and other potential hazards or anomalies in the areas to avoid having courier drivers lose time or fail to meet a pick up and delivery task.

Time management and keeping on top of things is incredibly important to the dispatcher, as this allows for optimal use of driver resources and enables better delivery services. Services can range between 30 to 60 minute pickup and delivery tasks, to overnight and national line-haul freight. Not to mention national or international airborne or water bound shipping. In local based freight management, if drivers are running behind schedule then it makes it difficult for the dispatcher when assigning new jobs. If dispatchers are faced with a situation where they need to reassign jobs from one driver to another due to poor scheduling, then this creates undesirable frustration and increased mental load as well as additional operation costs. This also affects situational awareness and is an obvious sign of poor operational performance.

FIGURE 3.3: A courier making a pick up from a retailer.

3.4.2 Courier drivers

Courier drivers are tasked with the actual pick up and delivery of goods from either customer to customer, customer to depot or depot to customer. They could be considered to be the backbone of the freight delivery service. They are usually paid a commission on how much freight they deliver. Couriers either operate a van for light metro based freight, or have a truck for bulky items. The more packages they can transport the better their income will be. They heavily rely on the Dispatcher to give them delivery details or job orders. At the beginning of their shift, they can have a fully loaded vehicle ready to deliver to customers on a known route. This route is optimized for specific deliveries in a topological area. They can also pick up and deliver throughout the day on an ad hoc style basis, or on route to another job. It is important that they run as efficiently as possible between freight hubs, to minimise their fuel costs. Knowing the position of where these drivers are and their route is vital information for a dispatcher to make decisions. Some drivers travel between cities and are known as line-haul driver's. line-haul drivers usually take freight from another city directly into a local depot, where forklift operators either unload the freight to be sorted by the location to which they are going, or load sorted freight onto the truck to be transported. The courier drivers are the first point of contact with the customer, so it is essential that they leave a positive impression that their goods are in safe hands and will be delivered in a timely manner.

Requirements: Couriers are required to run specific routes throughout the day of trading to optimise the use of fuel and also to create the shortest time windows of pick ups in order to increase their income. They are also expected to veer off course should there be a pick up opportunity near to them, or on route. They are expected to work with the Dispatch Operator to form the front line of the freight company. On occasion, if they are carrying a large item or bulk-order, the line-haul driver can offload the goods directly to the delivery point. This is called a bulk-delivery and is more favoured for the company, because it requires less handling on their behalf. This benefit enables a lesser chance of the item being damaged as well as faster delivery speed for the customer. This also has a positive effect on the task completion and time management ability for the dispatcher.

3.4.3 Customers

The Customer is the reason for and focus of the courier industry. Without the customer there would be no need for courier operations. It is very important to consider the needs of the customer as they provide the financial resources and the delivery items essential for the freight operation. It is important to make sure that the customers needs are completely satisfied so as to maintain a good business record of reliability, timeliness and cost effectiveness in serving customers. Such a reputations is vital to the continuation of the Freight company.

Requirements: Customers initialise the order with the freight company and provide a pick up or delivery address so that the courier driver has something to carry. There are no specific requirements for the customer other than signing and packaging goods. As they are on the receiving end of the service the satisfaction of the customer is held as being the most valuable part of the operation.

Chapter 4

Prototype Development

4.1 Design Process

In this section the author discusses the interaction design process of developing an ideal prototype system that would be deployed into the dispatcher environment. A key functionality of the prototype system is to communicate situation awareness to optimize decision making while minimizing the impact of disruptions. The prototype system includes two main components: the display and the controller. The thrust of this thesis is to introduce the NUI technology in hope that it may be used often as a primary mode of interaction with multiple large screen displays. To address this problem, we use a systematic design process to design and evaluate the prototype hardware system for specific use in the courier dispatch and freight management scenarios.

To approach this design the author uses a User and Task centric design methodology. By analysing and acknowledging the various tasks the user is expected to complete, a system can be designed around facilitating the users expected work outcomes, but also acknowledges the medial tasks and other systematic processes that are required to maintain to the flow of freight. With this iterative design approach, we can address the requirements of the users as well as other stakeholders. As iterations of the prototype system have been designed and constructed, they can also be tested using a common experimental study with subjective feedback about the modes of interaction to ensure a high quality system is created. This experiment will provide empirical data that can be used to analyse the system itself in terms of its efficiency and functionality, as well as gain information on the likeability of the prototype interface.

After running through the expert user interview and using the information gathered through observation, (especially based on the type of mentally intensive work to which the dispatchers are subjected), we can specify the final system configuration needed to facilitate a high amount of information throughput as well as provide a high amount of functionality for the dispatcher to process jobs. By using state of the art graphics accelerator technology, a computer system could be assembled using several monitors. The particular graphics card that was used was an N-Vidia 670 Series Graphics card, which is capable of running up to three monitors on its own. There are other graphics accelerator cards available from AMD which currently allow for up to six monitors off a standalone graphics card. Both N-Vidia and AMD graphics processors may run additional monitors by installing and running graphics cards in special bridged modes such as AMDs Crossfire or the N-Vidia SLI. These special modes enable the graphics accelerators to work with each other and share resources, which enables them to do much greater data processing and in turn, be able to present more information to the user by providing the additional output.

4.2 Interface Sketches

Figures 4.1, 4.2, 4.3 and 4.4 are sketches were produced to put forward design ideas to the partner company on the project, Blackbay Ltd. Blackbay are an innovation company that create mobile and other technology solutions for the freight industry worldwide. In the early design phase, the sketches were presented to the engineers from Blackbay as potential interface designs with the various NUI technologies as concepts for the prototype dispatcher system. Discussions ensued about the prospects of each approach and feedback was provided about which of the prototype designs were preferred by Blackbay and why.

From these sketches, the preferred option was the horizontal three screen wrap around style as it provided the necessary screen area to present a large amount of visual information at any given time. The Horizontal side-by-side arrangement 4.1 was also preferred because it enabled the viewer a natural reading layout for the information and because all of the information screens were in view of the dispatcher in such a way that provided instantaneous panoramic viewing without too much head movement. The vertical arrangement 4.2 did provide less fatiguing NUI interaction with the touch screen, but reduced the useful desk space needed for handwritten documents.

4.3 Iterative Design

After receiving feedback from the blackbay engineers, about the prototypes presented previously in section 4.2, the author iterated the Figure 4.1 design option to achieve a

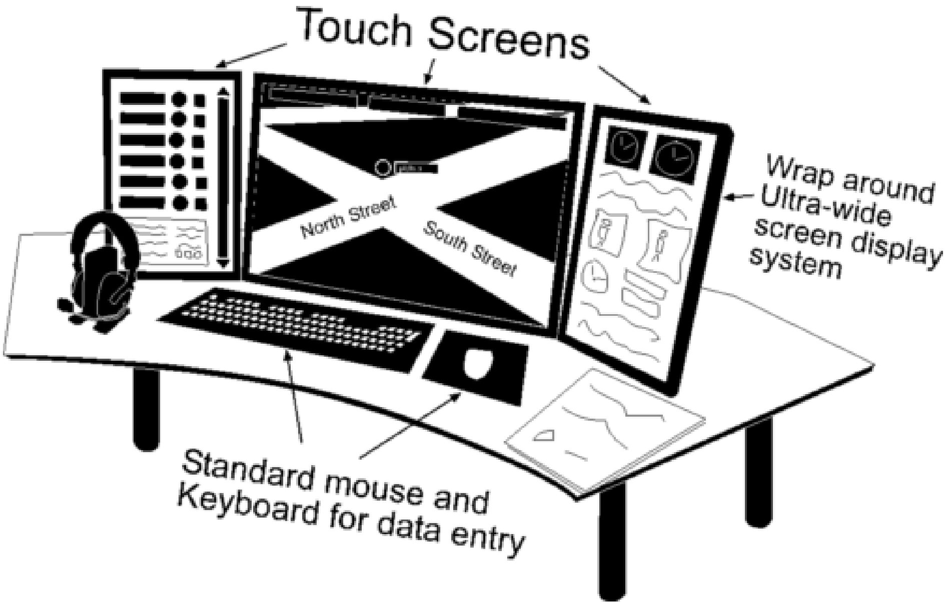

FIGURE 4.1: sketch one of interface prototype showing Horizontal Touch-screen arrangement

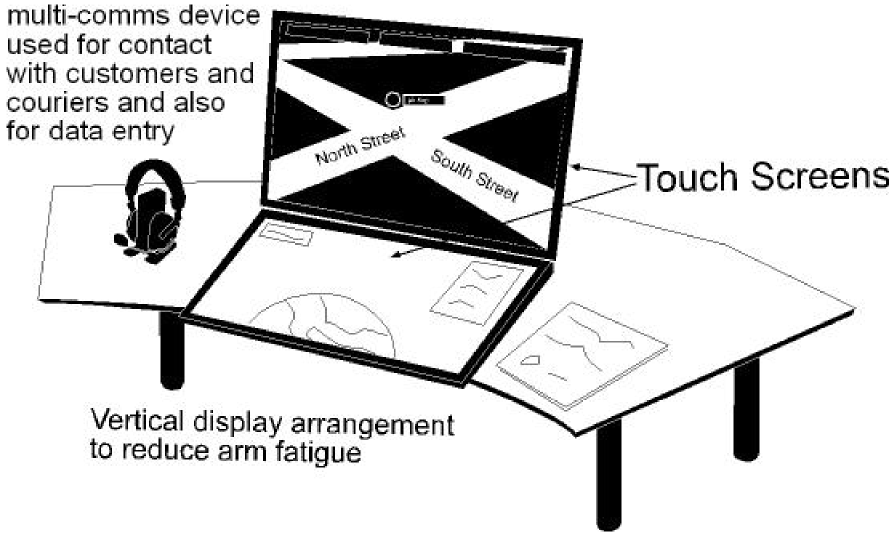

FIGURE 4.2: sketch two of interface prototype showing Vertical Touch-screen arrangement

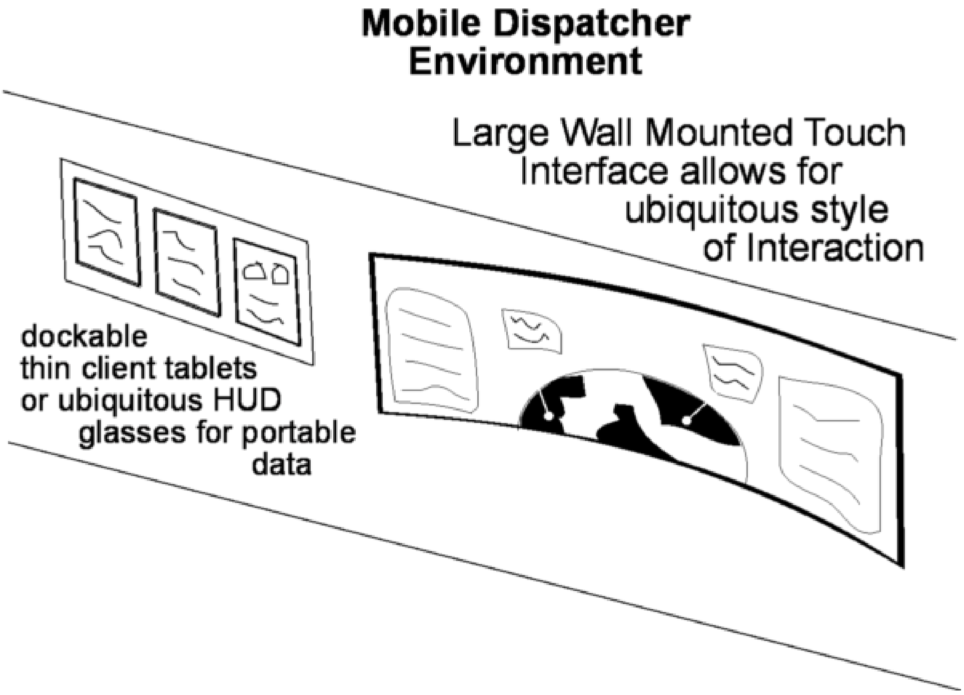

Figure 4.3: sketch three of interface prototype showing Mobile Dispatcher Station

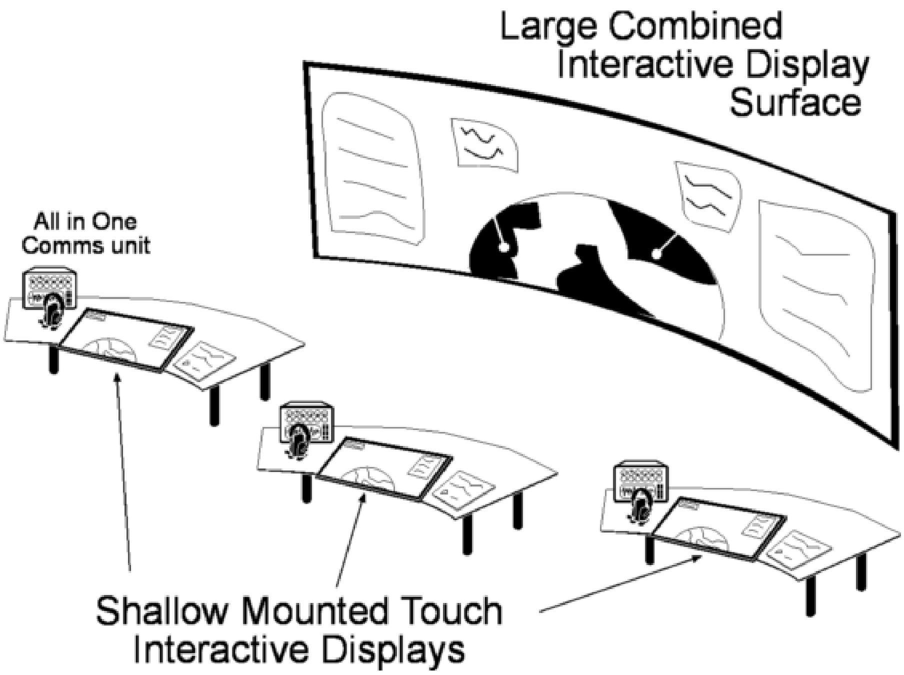

Figure 4.4: sketch four of interface prototype showing Shared Working Environment

workable display configuration of the system components including the necessary hardware and software components to test the concept. This configuration also provided a platform for investigating the various NUI technologies that would facilitate interaction with the display system. Engineers comments on the multi-touch interface was that by having multiple screens required there to be additional touch overlays on the other monitors in order for the touch interaction paradigm to be properly supported. It was noted that the gesture and multi-touch interaction would work better over a larger surface or onto additional monitors, so that information could be exchanged between the displays in an intuitive manner. It was also stated that having the displays in a horizontal layout was more natural as people tended to read from left to right, not up and down.

4.4 Final Design

The final design of the experimental prototype dispatcher workstation is shown in 4.5. This system consists of a triple monitor system with one large 32 main display and 2 peripheral 22 displays, configured to be run in portrait mode, positioned on either side of the main display. Additionally the platform includes four interface devices, a traditional optical mouse, a trackpad, the LEAP motion sensing system (for gesture tracking) and the integrated touch sensitive screens on the three displays.

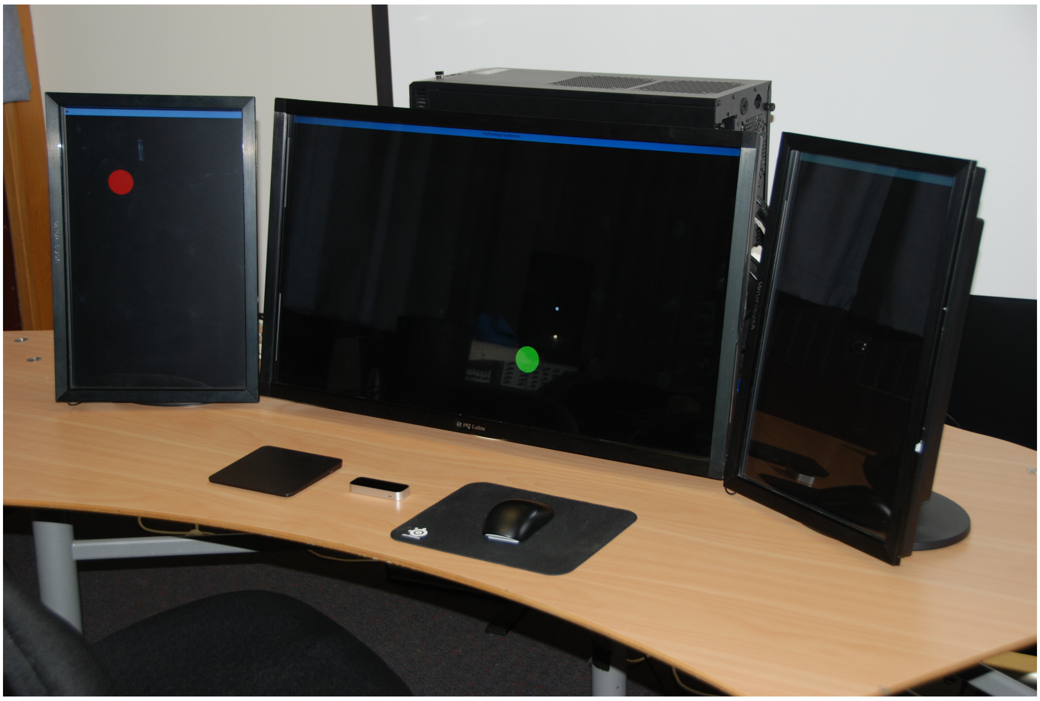

FIGURE 4.5: The complete test interface system with each of the devices shown

4.5 Prototype Evaluation

To evaluate the developed system, it would be best to have the target user perform the experiment and have a software prototype suitable to the taskwork of the disptacher. For this thesis however complications arose for evaluating against the dispatcher, as it was difficult to organise a statistically significant amount of dispatchers to perform an experiment. In order to evaluate the effectiveness of the final design, a method of evaluation was required to show some the effects of the NUI technology. It would be beneficial for the experiment to provide generalised data, so that the results can be compared catagorically. This is where experiments such as Fitts's Pointing experiment [28] would be a useful way to measure the performance of the NUI devices. Many questions can also be answered by using of Fitts's Law where the Index of Difficulty can be used to compare the different user input devices 4.6. If we can compare the different performances of the devices against the conditions such as a pointer target size and the distance required to traverse a pointer to a target, then we can evaluate the interface systems against each other in a statistically comparible manner.

$$ID = \log_2(2 \times D/W)$$

FIGURE 4.6: Fitts's Law where ID= index of difficulty, D = target distance W = width of the target

4.5.1 Prototype Evaluation Questions

What is the difference in task completion times for each interaction paradigm? If we take this measurement, we can identify which device performs better in the wide FOV display system.

Do the interface devices take an effect on target sizes? It is important to ask this question, because it defines the size limitations of the size of user interface targets to be matched the selected interface devices.

Do the interface devices take an effect on the size of the target seperation? This question is also useful to ask as it will help decide how information is positioned on the wide FOV display system.

Do NUI gestures aid in the performance and task completion of a typical courier dispatcher? By comparing the different tools that allow for a gestural or multi-touch input which enables gesture interaction, interaction paradigms can be identified as performing better at certain tasks.

Chapter 5

Evaluation

In this chapter, we present the results of experimentation, observational studies and any survey or statistical gathering of information that is relevant to the investigation.

5.1 Evaluation Goals

The Primary goal for the evaluation was to test the prototype system for pointing ability within each of the input mechanisms to prove that the touch screen input mechanism is worthy of using in a repetitive task driven situation and comparable to the mouse in terms of task efficiency.

Specifically, the author hypothesizes that:
Natural User Interfaces perform better at pointing tasks than traditional interaction methods across a wide FOV Display system.

With the null hypothesis that:
There is no significant performance difference in NUI interaction styles over traditional interaction methods.

5.2 Apparatus

Figure 5.1 shows the experimental system consists of the following computational and peripheral devices in order to test out the NUI interaction paradigms. The computer system used was custom built with an Intel Core i5 quad core processor with 12gb of RAM matched with a Leadtek GeForce gtx670 graphics accelerator (see appendix E),

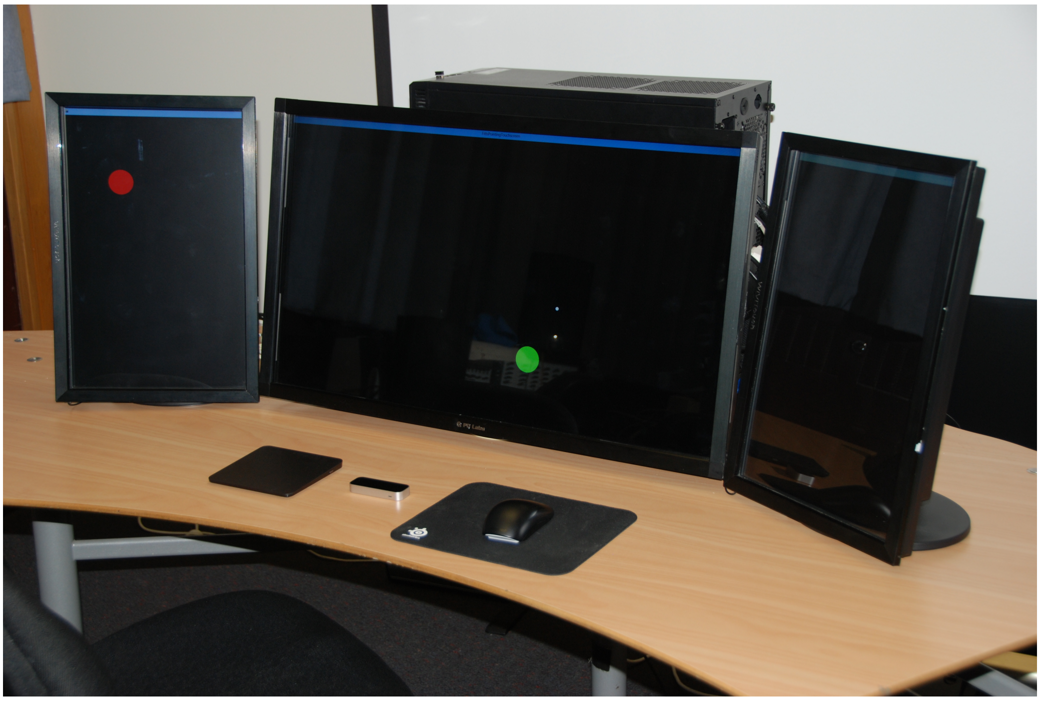

Figure 5.1: The complete test interface system with each of the devices shown

which was able to support the three monitors for the multiple monitor configuration. The monitor system comprises of a large 32" main display (Samsung MD32B Commercial LCD) and two 19" side displays (Samsung S19B420 LCD) configured to be in portrait orientations. As reported earlier in **??**Chapter 2) the reasoning for the three monitor system was due to the observational studies and expert user interviews performed unveiled that dispatchers would switch between approximately 3 or 4 different programs, so prototype provided additional display panels, (ideally one per program or task window) to provide the greater situational awareness through the larger FOV and the greater capacity of information presentation that comes with it.

The interface devices that are in the system are:

- 3 Multi-touch screen overlays for each monitor for direct touch interaction. (2 x WiviTouch WVT-M4/6R-19E 19" multi-touch overlay, 1 x PQ LABS G4 Series 32" multi-touch overlay)
- A Logitech T650 multi-touch trackpad gesture controller. Figure 5.4
- A LEAP Motion; touch-less hand and finger gesture controller. Figure 5.2
- A microsoft touch mouse baseline mouse pointing device. Figure 5.3

FIGURE 5.2: The LEAP Motion touch-less hand and finger gesture controller

FIGURE 5.3: The mouse used in this experiment Microsoft touch wireless mouse

FIGURE 5.4: The trackpad used is a Logitech T650 multi-touch wireless trackpad

5.3 Experiment Design

A Four-factor repeated measures design was used for the experiment. The main treatments were the four methods or devices used to interact with the three screen MMS, described in the previous section (i.e. the computer mouse, trackpad, touch screen and LEAP gesture control system. The task for the experiment was a pointing (or tapping type task) that was an adaptation of the traditional Fitts's law experiment. The experiment was designed using the Fitts's experiment to provide the ability to make comparison with the findings that similar studies performed with computer interaction devices. It was also chosen as a means to compare the four interaction paradigms. This style of experiment was also chosen to be similar to what would be expected of a dispatcher interacting with a computer display, but its focus was on the intuitiveness of the interaction mechanism at a basic level and not on the more demanding cognitive processes associated with dispatching tasks. As such the experiment used naive participants from the general public. If a larger base of dispatchers were freely available, the experiment would have been designed in such a way that would provide the greater cognitive challenges such as found in dispatching.

The authors method of testing pointing and tapping tasks associated with display interaction is an adaptation of the tasks originally designed and tested by Fitts [27]. In his original experiments, Fitts used a physical tapping medium with a stylus as a pointing tool. Fitts found that he could assess both the reactive and motor control processes in evaluating the intercept and slope of the tapping times when he varied the sizes and distances between objects being tapped. In the currrent design, we use a variety of devices attached to a computer that register user input for a cursor control. We can substitute the cursor on the screen for the tip of the stylus. Figure 5.5 shows a screenshot of the display used for the tapping experiment. The subjects task was to position the cursor (in the case of the mouse, trackpad, or LEAP Motion controller) or place their finger directly on the screen (as in the case of the touch screen controller) on the green dots. Once a green dot was designated, then the red dot would turn green indicating requiring the participant to move quickly to that point on the screen. Note that each designation would not be completed until the cursor (or finger) were within the diameter of the target for at least 200ms. This is eliminate accidental scoring of the task the cursor sweeps through a target without landing. The size and distances of the dots were varied after each pair was designated by the participants, the software was designed so that no two paired target locations would be repeated. The targets were also randomly reversed so that participants could not predict where the starting target would occur. Approximately 650 lines of code were written to automate this experiment.

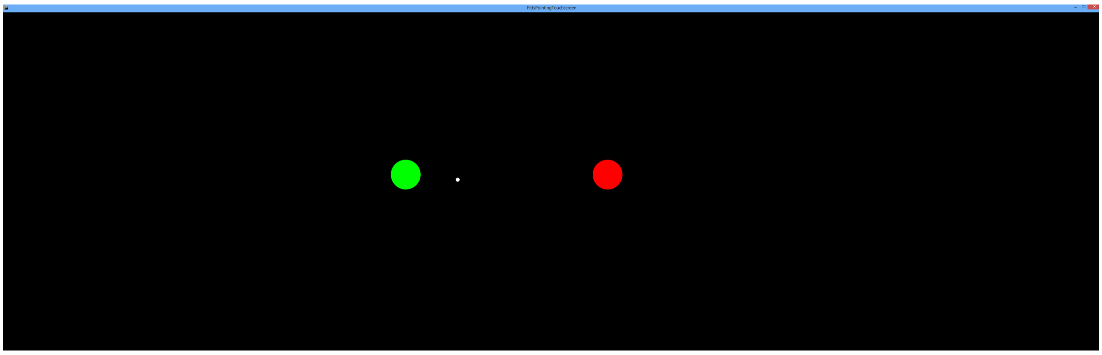

FIGURE 5.5: Screenshot of the experiment display window

All 25 subjects received the four treatments with the order of presentation balanced across subjects. Two sizes were used for the targets on the screen (large = 50 pixel radius and small = 25 pixel radius) and the distances between targets were discrete distances of 384 pixels to 3178 pixels. For each treatment, 113 target pairs were presented (with the varying size of targets and distances between targets). For each treatment the order of presentation of the target pairs (combinations of size and separation distances) were the same for each participant. (In subsequent data presentations, the target separation distances are often shown in pixels. One pixel is equivalent to a distance of 0.265mm.

5.4 Measurements

The dependant variables for this experiment were:

1. The total time (in milliseconds) to complete each treatment. This consisted of 113 target pairs including two large and small size conditions and the range of distances from 384 pixels to 3178 pixels.

2. The response time (in milliseconds) for each target pair.

The measurement value obtained from the prototype experiment was the response time and total task completion time metrics, which are both derived from time in milliseconds. There is also demographic information that was acquired from participants to give an understanding of the user group for the experiment.

5.5 Participants

Twenty-Five (25) participants (16 male, 9 female) between the ages of 20 and 36 were recruited for the empirical study from around the city of Christchurch, New Zealand.

As shown in appendix B, their skills with computers vary from being just below average to highly prolific. There were 16 male and 9 female participants. Participants were most experienced with using the computer mouse and the track pad and had very little experience with large touchscreens and even less experience with gesture controllers like the LEAP Motion or the Microsoft Kinect. All participants except for one had no experience in dispatching operations. Please see Appendix B for the graphs.

5.6 Materials and Procedures

The following materials were used to run the experiment:

- Isolated Experiment Room
- Ergonomic Desk and Chair.
- Prototype Human Computer Interface.
- 10.1" Tablet.
- Information sheet and Consent Form, see Appendix F.

During experimentation, participants were asked to complete questionnaires before and after the experiment. These questionnaires are shown in Appendix D. The participants completed the pointing tasks across the four different interaction device treatments. Subjects were given practise time to gain understanding with the devices, and well provided adequate rest time to relieve any effects of fatigue between treatment runs. The Participants are given a brief overview of the interaction method with the controller, so they are equipped with knowledge about how the devices behave.

5.6.1 Experimental Process

The process of the experiment was as follows;

1. Participant is given an information form and signs the consent form after acknowledging what is their expected contribution (Appendix G).
2. Participant is asked to complete the demographic questionnaire (Appendix D) used to identify the participant pool and their ability with computer interfaces and their general ability to use a computer.

3. Participant proceeds to perform the first treatment of the experiment, the order of presentation being balanced accross all participant.

4. Participant proceeds to perform the ten practise set of tasks for the given interface experiment.

5. Participant then proceeds to perform the 113 tasks of the real experiment.

6. At the end of the experiment, the participant is given a five minute rest, then asked to complete a subjective questionaire.

7. The participant repeats steps 3 - 6, until all of the interface device treatments have been completed.

This process is followed until all four treatments have been completed by the participant. They are then given their reward of chocolate and food voucher on the successful completion of the experiment. The balanced condition presentation order was necessary to ensure that the experiment results were free of effects of cumulative fatigue or learning effects. Figure 5.6 shows a participant performing the touch-less interaction technique for the LEAP treatment of the Experiment.

5.6.2 Pilot Testing

To validate and tune the experimental testing procedure a 3 person pilot test was executed in order to test the experimental setup. (Note: The pilot subjects were not included in the participants in the main experiment.) During testing, it was noted that in order to ensure the test results were fair among the interface devices, the study had to be executed in a tightly controlled manner using a balanced design. For the test to be

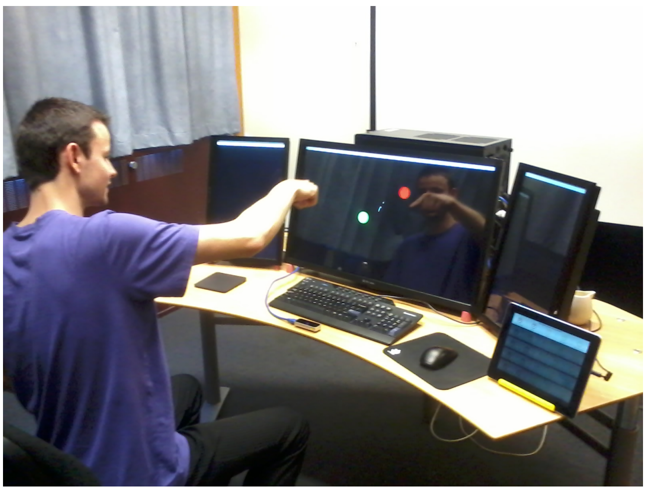

FIGURE 5.6: A Participant using the LEAP Motion controller

effective, each participant needed to perform the exact same combination of target sizes and distances as any of the other participants. Acknowledging this fact, the experiment was further designed to ensure the same targets where presented in the same order for each participant. It was also necessary to provide fixed locations for the targets, so that there was a specific target grid that creates reference points for each target. The test was designed so that each possible combination of targets had been selected for each trial run. Setting these limitations, enabled analysis of the results with more rigor regarding inferential statistics. The devices were also tuned to provide the best interaction experience for each treatment. For the touchscreen interaction during pilot testing, the participants were allowed to use either one or two hands during the task. This was done to test the effects of the single hand interaction versus two-handed interaction, to see if there was any measurable differences in response times. Although it was apparent that the two-handed interaction technique was superior to the single handed technique (especially for the larger separation distances between targets) it was decided that it was not a fair comparison with the other interface devices, so participants were restricted to single hand interaction making the interaction similar between the different interface devices. Additionally, the gain on the mouse and trackpad were adjusted so that the total excursion across the three screens for the large target separation distances could be made with a single mouse or touchpad finger movement without clutching the device.

Chapter 6

Results

6.1 Results

From the results drawn in the pointing experiment, we have subjectively and holistically measured the performance of the interface devices. It was shown that the two interaction styles, the multi-touchscreen system and the mouse, provided the fastest response times for target selection tasks.

6.2 Statistical Results from Experiment

In this section, we show all of the statistical evidence of the experiment, this is used to make claims on the task efficiency aspect of the interface design. In this experiment, 26 participants completed the four conditions, but one particant's data was removed due to excessively poor performance with the LEAP.

6.2.1 Completion Time

Was there a difference in response times across the four Interface conditions and did it vary with distance?

Figure 6.1 provides a summary of the mean and standard deviations of the total time required to perform each of the treatments collapsed across all of the target conditions. Since all of the subjects received the same combination of targets, this Figure provides a good summary of the total effort required to preform the tasks across the four treatments. The devices were found to have to following average total task completion time; the

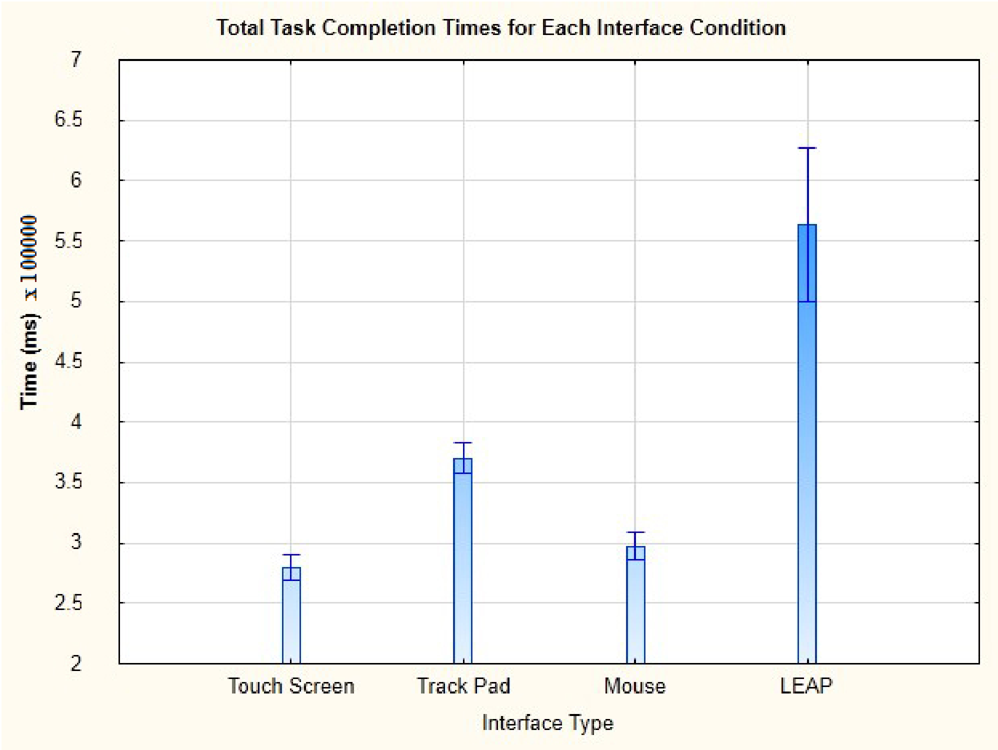

FIGURE 6.1: Total times taken to perform task across all interfaces

LEAP Motion took an average of 563,155 ms, the Trackpad took an average of 370,299 ms, the mouse took an average of 297,422 ms and the touchscreen condtion took an average of 279,514 ms. The mean data show that both the mouse and touchscreen treatments provided the shortest times to completion whereas the Trackpad and the LEAP Motion controller showed increased times to completion.

An ANOVA was performed the individual data to test for main effects across the different treatment (interface type) conditions (LEAP Motion, Mouse, Trackpad, Touchscreen) a statistically significant main effect was found for the treatment type. Post-hoc analysis was then conducted using a Tukey test (Appendix B, table B1) showing that there were highly significant differences in the total times for all combinations apart from the mouse and the touchscreen, which had similar response times.

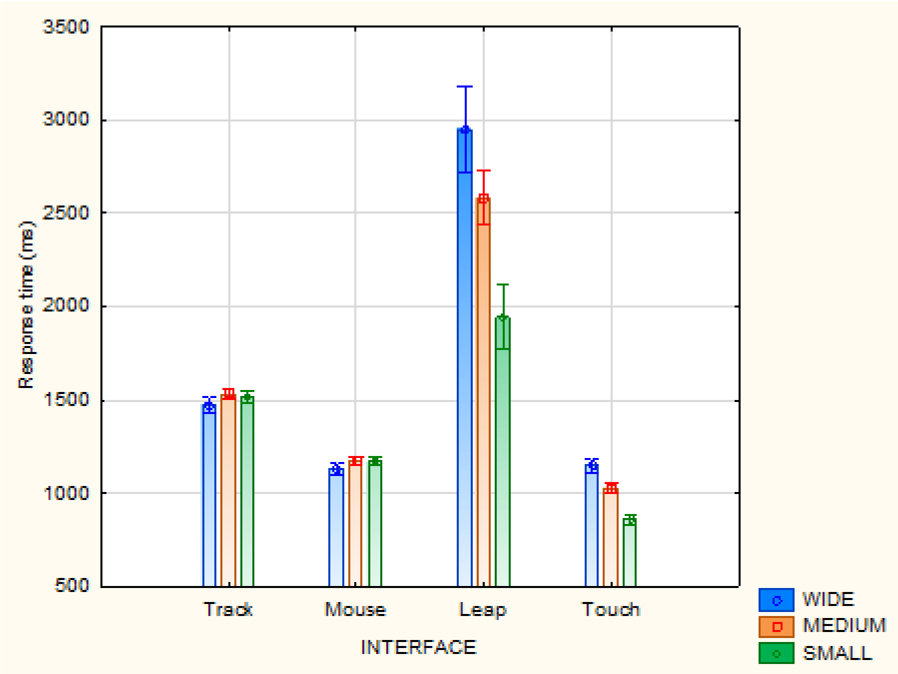

FIGURE 6.2: Average Response Time in ms for each interface against Small, Medium and Wide target seperation distances

6.2.2 Distance Between Targets

Was there effect on response time over varying distances?

Figure 6.2 shows the mean completion times for the four interface treatments for target separation as grouped into three distances and collapsed across both target sizes. These data show that target separation had a greater influence on the Leap and Touchscreen interface than on the trackpad and mouse.

6.2.3 Target Sizes and Distance Separation

Figures 6.3, 6.4, 6.6, 6.5 show the mean and standard deviation of the response times for the three separate distance groupings (Small, Medium, Large) and for the two target sizes, Large and Small.

Was there any significance for the Target Sizes over varying distances?

A series of ANOVA's were calculated to test for interaction and main effects for the size of the target and the varying distances, reaction time being the dependent variable shown in the following pages.

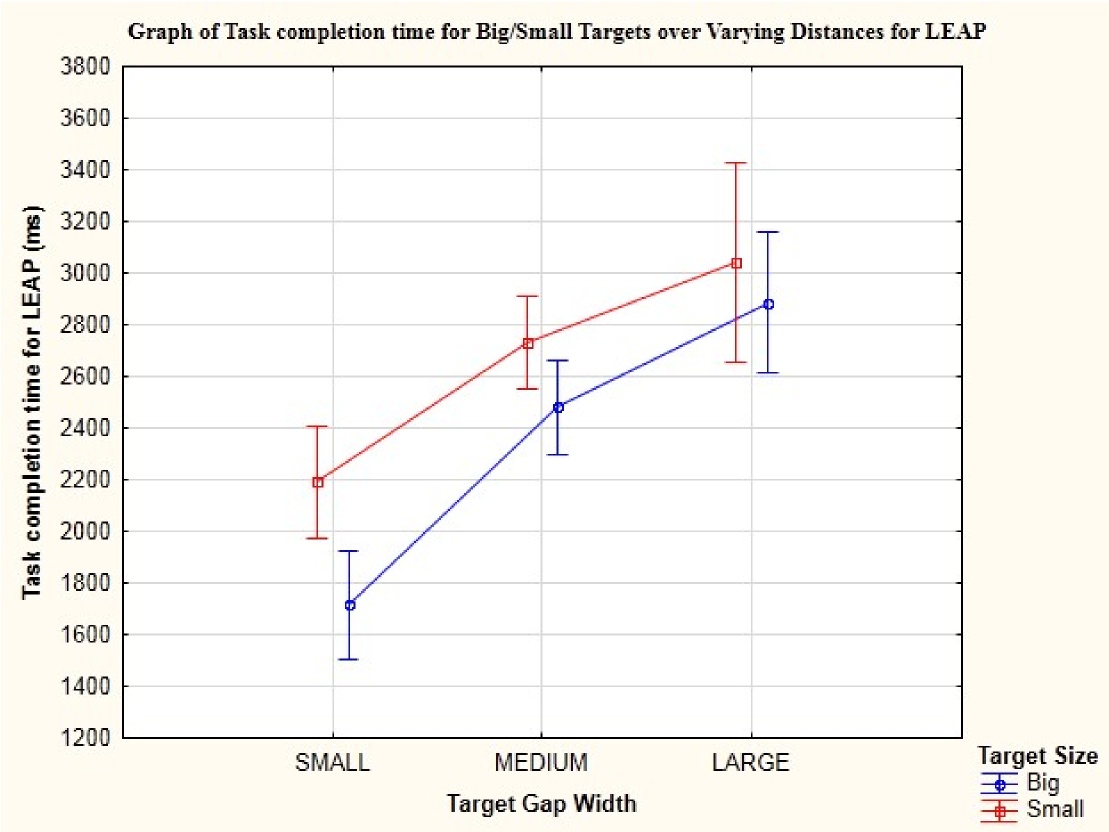

FIGURE 6.3: Response times for the Leap Controller showing distance effects

LEAP Motion Shown in Figure 6.3, for the LEAP Motion condition, no significant interaction effect was found for target size and distance, F(2, 2794)=.87549, p = .41677. However a main effect was found for the distance category of small, medium and large target separation distances, F(2, 2794) = 32.448, p=.001. Post hoc analysis by means of a Tukey test revealed significant differences amongst all combinations, in order from fastest to slowest being small, medium and large. Likewise a significant main effect was found for the target size independently, F(1, 2794)=7.9397, p = .005. A Tukey test revealed that these responses were significant quicker for the big target size.

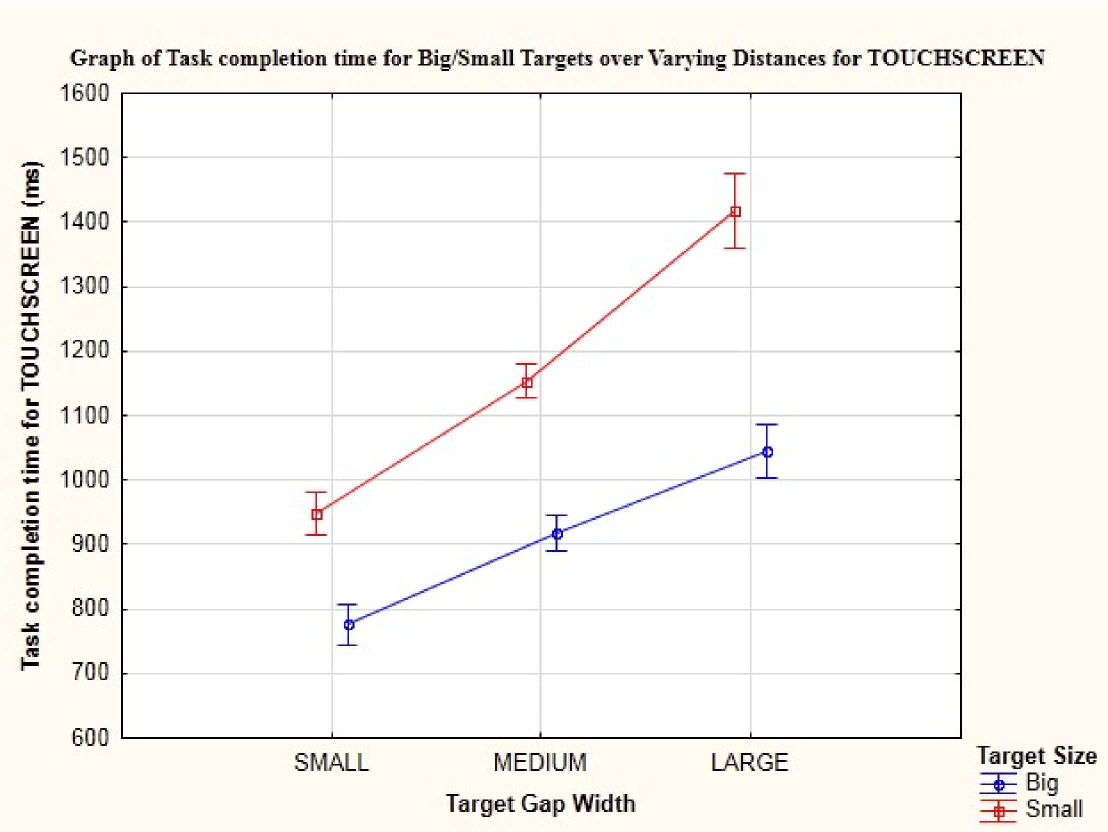

FIGURE 6.4: Individual Task Completion Time of the TouchScreen Interface

Touchscreen In this condition was a significant interaction effect: F(2, 2794)=11.172, p=.001 As shown in Figure 6.4 and confirmed by Post hoc analysis found all combinations were significant different to each other except for when the target was small at a small distance compared to a big target at a medium distance. A main effect for distance, F(2, 2794)=158.08, p=0.001. As shown in Figure 6.4 and confirmed by Post hoc analysis found all combinations were significant different to each other except for when the target size was small and the distance at which the targets were separated at a medium distance. Post hoc analysis by means of a Tukey test revealed significant differences amongst all combinations, in order from fastest to slowest being the small, medium and then the large. Likewise a significant main effect was found for the target size. A Tukey test revealed that these responses were significant quicker for the big target size under the touch screen interface condition.

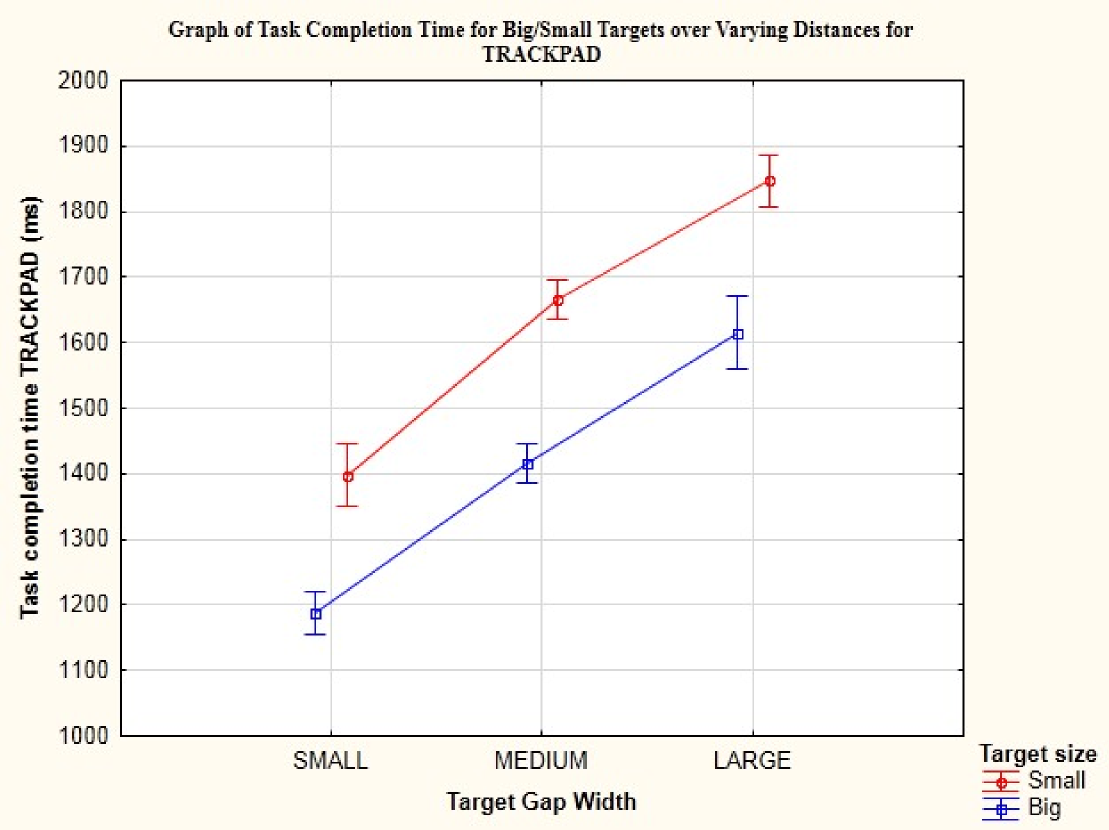

FIGURE 6.5: Individual Task Completion Time of the TrackPad

Trackpad The trackpad response time for small and big targets was found to be non significant 6.5, F(2, 2794)=.59737, p=.55033. A main effect for the target distance was significant, F(2, 2794)=190.26, p=0.001. Post hoc analysis of all combinations reveals that all combinations were significantly different to each other except for when the target size was small and was at a small distance, compared to a big target at a medium distance. A significant main effect for size was found, F(1, 2794) = 184.12, p=0.0000. The Tukey test revealed that responses were significantly quicker for the big target size.

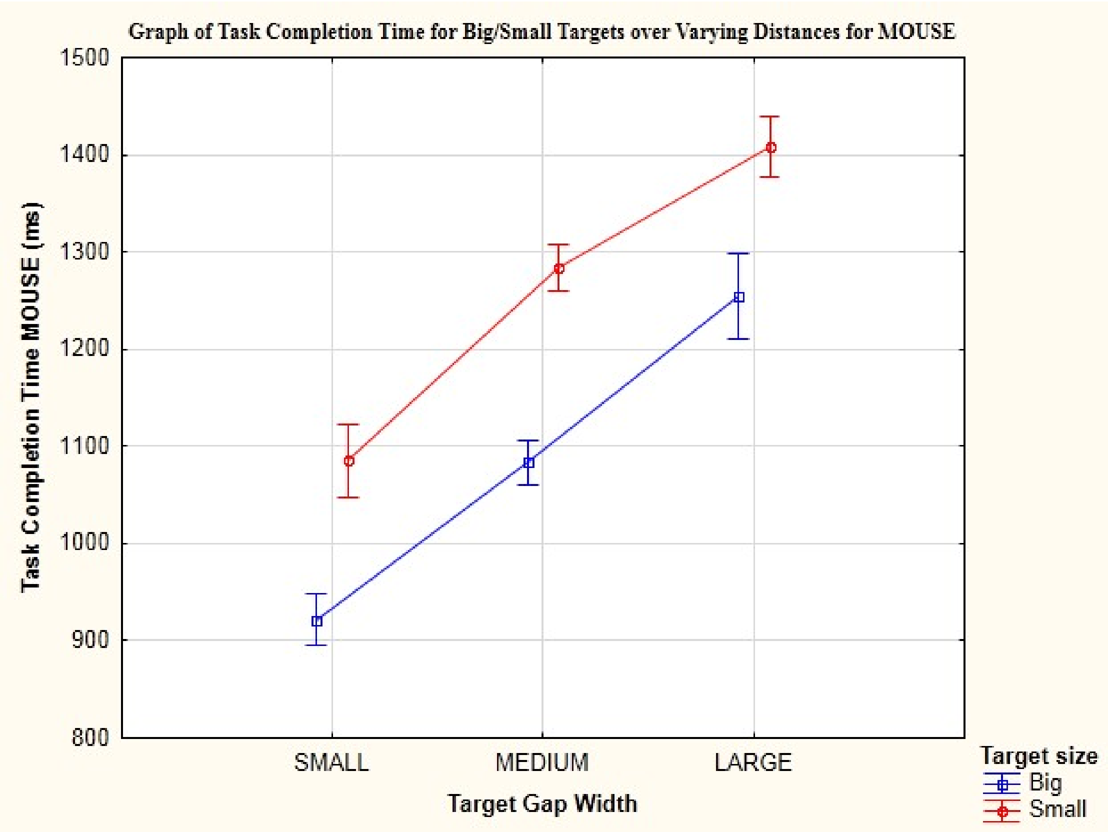

FIGURE 6.6: Individual Task Completion Time of the Mouse

Mouse For the mouse, the interaction of size, distance and response time was found to be non significant, 6.6 $F(2, 2794)=1.4203$, $p=.24180$. However a significant main effect was found for target separation, $F(2,2794)=171.34$, $p=0.001$. A significicant main effect for size was also found $F(1, 2794)=167.41$, $p=0.001$, where a Tukey test revealed that responses were significant faster for the large target size.

6.2.4 Modelling the Data

Figures 6.7, 6.8, 6.9 and 6.10 show scattergram plots of the response time data for the four interfaces treatments as a function ofthe Index of dificulty specified by Fitts'. All conditions were significant with (r=0.5081, p <0.0001) was found (Figure 6.10) for the Trackpad. The trackpad intercept and slope was found to be -290.653 + 0274.032x. For the mouse condition (Figure 6.9) a significant was found (r = 0.395, p <0.0001) with y = -144.611 + 198.914x. For the LEAP controller condition (Figure 6.7),was found to be significant with (r= 0.0473, p <0.1), y = 1544.93 + 135.701. Finally for the touch screen (Figure 6.8, a significant effect was found (r=0.4172, p <0.0001), y = -283.575 + 198.691x.

As anticipated from observing the scattergrams and previous data representations, the mouse and touchscreen were influenced least by target separation. The degree of influence can be can be represented by the slope of the linear regression equations (i.e. 0.208 ms/pixel for the mouse and 0.174 ms/pixel for the touchscreen). The intercepts for the linear regression according to Fitts [27] can be described to the initial preprocessing time before the motor response is made. In this condition, the minimum Index of Difficulty was 4, which is approximately where the intercept is for the linear equation. These show that the touch screen on average has a 86 ms preprocessing or reaction time advantage over the mouse. The implications of these findings will be discussed in the next chapter.

6.2.5 Multi-Touch System Performance

This interface style was proven to be more effective at pointing and selection tasks than the other interface systems. It was shown to be the fastest system to complete the entire task of 113 targets. This was also found to be statistically significant, which suggest that the Touchscreen System is a good solution for the wide display MMS.

6.2.6 LEAP Performance

The LEAP gesture controller, while it shows good fidelity for hand and finger recognition, it proves difficult to use it in a way that you would use as a traditional mouse and cursor style interaction. This effect showed through during experimenting, when it was used to perform at the extremes of the wide display MMS. The participants found it very difficult to use when trying to hit targets in the very extreme Left and Right of the MMS. This is evident when looking at the results of the Average Response Time Graph 6.2 and also in the Graph of task completion for Big/Small Targets over varying distances

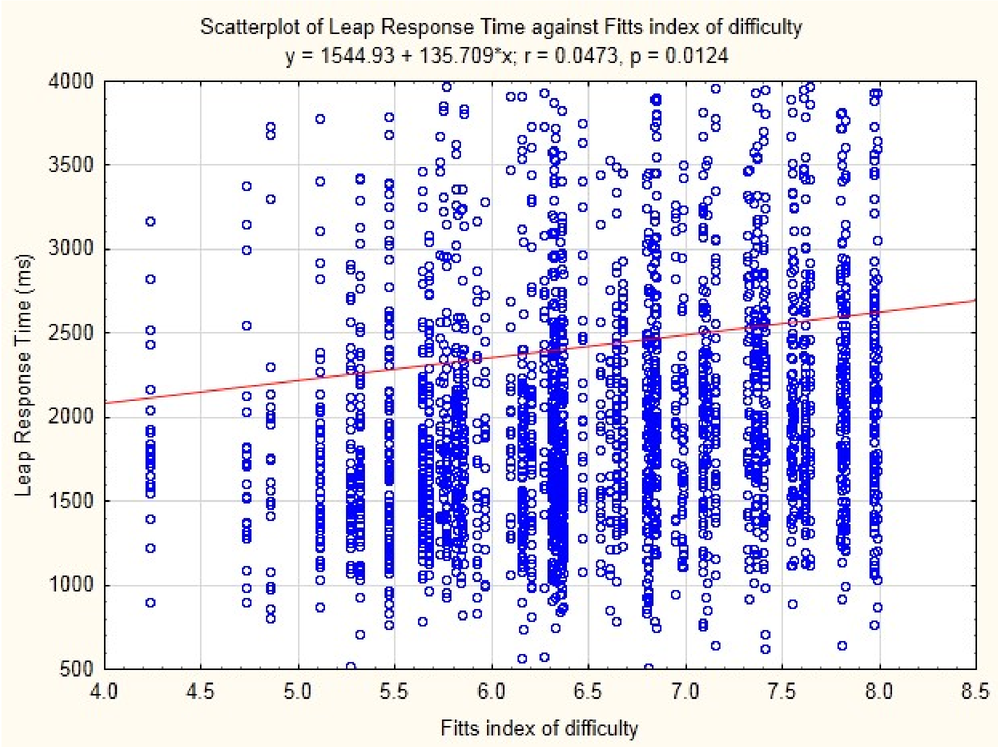

FIGURE 6.7: Scatter Plot of the response times for the LEAP condition against Index of difficulty

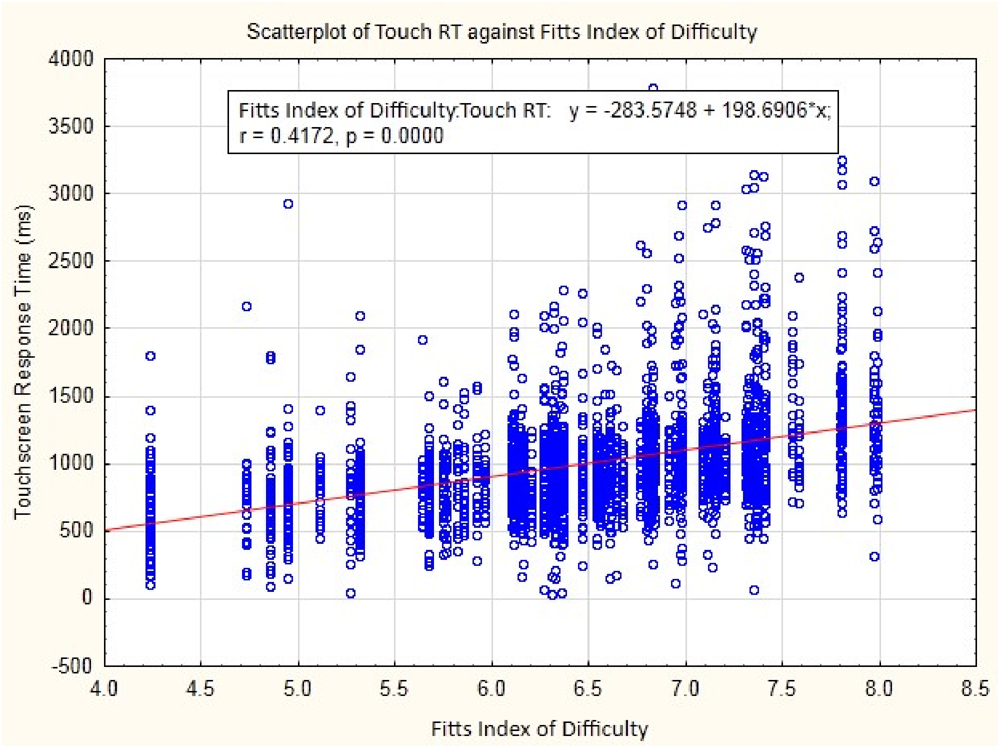

FIGURE 6.8: Scatter Plot of the response times for the touchscreen condition against Index of difficulty

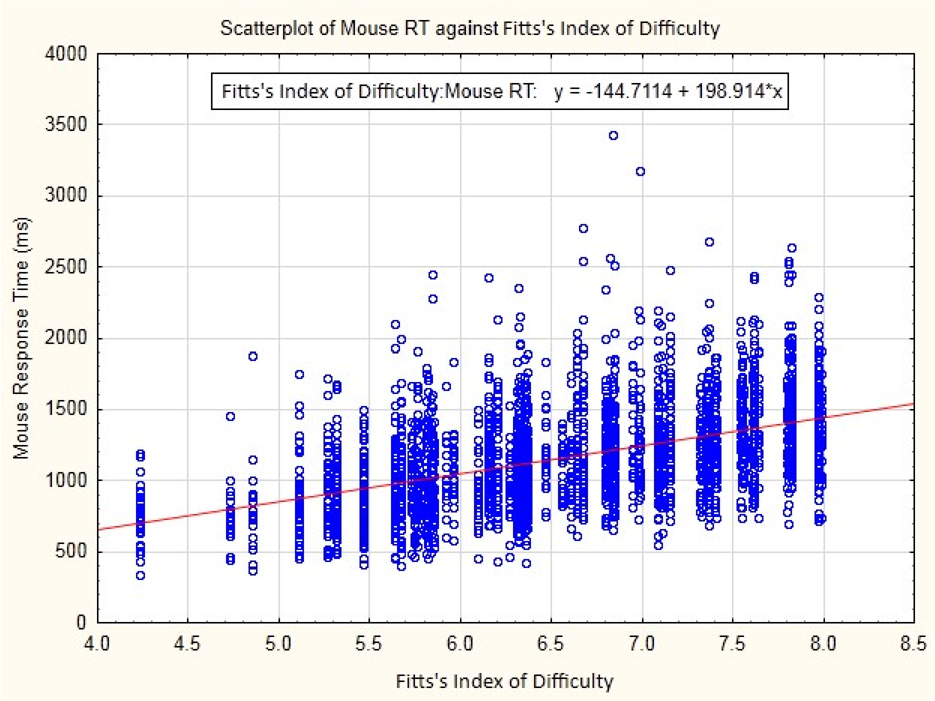

Figure 6.9: Scatter Plot of the response times for the mouse condition against Index of difficulty

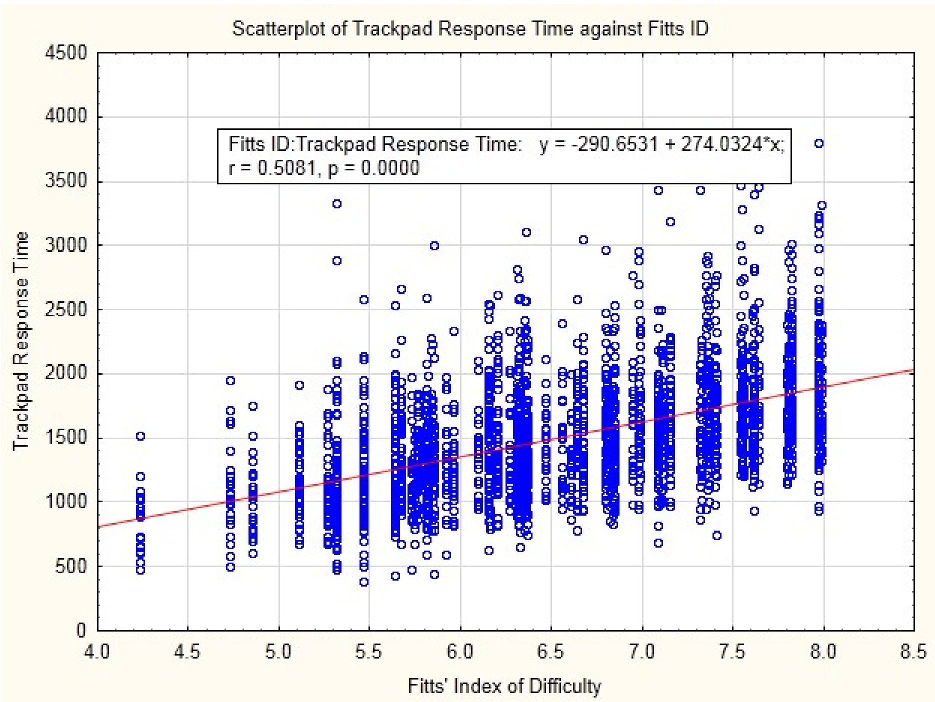

Figure 6.10: Scatter Plot of the response times for the Trackpad condition against Index of difficulty

6.3, where these graphs show that the response rate for smaller seperation gaps were considerably less than medium and wide target distances.

6.2.7 Multi-touch Trackpad Performance

This style of interaction performed the second poorest out of the four styles. While the device allows for rich touch and gesture interaction without obscuring the users view, it did not perform well for a repetitive pointing task. There may be other benefits to the Trackpad in the form of gestures, which was not explored as part of this experiment.

6.2.8 Mouse Performance

As the de facto control style for computers and also as the control group for this experiment, the mouse performed the second best behind the direct touch interaction. This makes sense and will probably hold true until there is a paradigm shift in how we interact with computer systems in the future, with NUI devices or with some other input mechanism.

6.3 Threats to Validity

Expert/Novice participants

The pool of participants contained mostly non-professional people who had very little education in dispatching if any at all. There was one Expert User who did perform the experiment which was valuable to development of the interface. It would have been better if the participant pool mostly comprised of expert users, but this was not an option for this study, as it would have taken a significant amount of time to organise enough expert users to participant in the experiment and would be a costly procedure. Therefore the participants were selected from the general public of Christchurch New Zealand.

What about the Effects due to fatigue?

When conducting the tests, there were certain flaws in the design that where attempted to be mitigated through the careful planning of the experiment process between participants. However Fatigue effects possibly had an effect greater than anticipated and possibly due to the repetitive nature of the task, the experiment became boring for many participants. This would have skewed some of the subjective answers.

was the task Un-fair task for the devices style of interaction? While the leap provide a unique touchless input benfit and looked to be an interesting tool for navigation, it did not perform so well in this testing condition. This was due to the device being pushed to its very limits, in terms of being able to navigate such a large area.

6.4 Qualatative Feedback

Most people found the LEAP Motion controller to be difficult to use for this particular task. This could be due to the controller being designed for more gesture based interaction, rather than for pointing style interaction. This is also supported with the results from the leap, where the smaller distances where much easier to reach rather than the medium and large separation distances.

6.5 Questions Unanswered

This section discusses the questions that were not answered in this research, but would be interesting to investigate further.

Is there a difference in information flow or bandwidth between verticle and horizontal screen configuration?
It would be interesting to compare the targeting difference in a full vertical display system, much similar to this current system and perform the comparison, to see which of the devices would be more efficient. This would show weather or not the vertical display system would statistically be good for performing dispatch or command and control tasks.

Does the wide FOV display system enable a dispatcher to make better decisions when performing problem solving tasks?
While it may have been shown that the touch screen is as efficient if not more so than the mouse for ultra wide screen pointer navigation, It did not show anything for navigation a GIS Map system, which is a 2D/3D hybrid style computer software. This is where there is a possibility for the LEAP system, as it is a device that operates in three dimensions, compared with the mouse which pointer navigation is limited to two dimension, it would seem the style of interaction would be more appropriate for this task, so an experiment could be run where participants would perform a 3D navigation task through a 3D environment.

What about the information?

How to spatially present information for such a GIS system and comparing different methods of representing useful data would be beneficial in a real-time, as it would help Dispatchers create a greater mental model to assist in Situational Awareness. It would therefore be worth developing and testing a system that is tuned to both the task of maintaining a mental model of where the drivers are while juggling critical information about the load of the drivers and the rest of the system. If there was such a system that could take advantage of the NUI functionality, it would be useful to test if this type of system could assist in Dispatcher performance.

What about the gestures?

All of the devices tested allowed for a richer set of interaction methods offered by gesture interactivity. Being able to register multiple finger and hand motions allow for a rich set of commands for navigating with a digital desktop. In this experimentation however, none of this functionality was explored and would be interesting to investigate how this functionality can be optimised for dispatcher use.

Does NUI technology increase the task effeciency of a courier operation as a whole?

As stated previously, the NUI system should enable a courier and freight management company to operate more effeciently. However the experiment did not facilitate this specific aspect. This would involve a fairly timely investigation and testing with multiple companies to test for the effect. The limitations of the research timeframe did not allow for such an experiment to take place.

6.6 Results Summary

For the pointing experiment, all of the devices performed differently except for the mouse and the touchscreen interface. These two conditions had a similar completion time and response time for the pointing task. It was shown that there was a significant effect between the two conditions. The trackpad performed second to last against the other devices, while the LEAP had performed the worst. The results for the LEAP were probably due to the fact that the controller is designed for 3D interaction as opposed to 2D interaction. These findings are further discussed in the future research section 7.

Chapter 7

Conclusion & Future Research

7.1 Conclusion

This research has provided technical insight into the interaction methods that could be applied to command and control interfaces for applications such as courier dispatching.

Based on the research the research reported in this thesis, it is clear that a touch screen interaction style when interfaced with a multi-screen wide display system is a viable way of embedding NUI technology in a courier dispatcher workstations far as pointing tasks are concerned. While it may not be used as frequent as the mouse and keyboard approach, touch screens may become more dominant as the technology becomes commonplace and the software user interface is built in greater accordance with the technology. Mobile technology will allow also factilitate the user to operate more freely without compromising the workflow.

By affording the use of touchscreen interaction for general and occupational use, the interaction would become more common place in the working environment and be developed as a learned modality much like the mouse. This change will not be so natural to some, especially those that are already conditioned to the mouse style of interaction. As touch interaction with computers becomes more common place, more people will be instinctively inclined to use it. To make the touch interaction more common place, computer systems will need to go under redesigns for example, the GUI will need to change to support the user modality of interaction, at the software interface and System level. By designing in this way, computer systems will be more in tune with the user. The software should also be set up in a way that easily allows for additional styles of interaction, so that the Interface is customised to the users favoured interaction style. This is where current systems fall short, due to the software interface and system elements not being created with the either user task handling in mind, or the way in which they operate the machine. Many commercial software systems do not allow for the true functionality of NUIs to shine through. Most NUI systems are seen as novel interfaces and reserved for gaming and other low level tasks, so a change in the way we design software for the future would be better to design the software interface to be customizable, to be able to re-tune the GUI to touchscreens and other NUI interaction styles like the LEAP Motion controller.

7.2 Contributions

Answers to the general research questions presented in Chapter 4

A functional prototype system that combines a wide FOV Multi-Monitor display system with Natural User Interface technology to use in courier dispatch scenarios.

An evaluation of the prototype which included a formal user study and a compar- ison of Natural User Interface interaction paradigms.

A software system that can be used to measure Fitts law and target pointing performance of Natural User Interface devices over a variety of display sizes.

A fully written and presented report on the research and its findings.

7.3 Future Research

The Author wishes to perform further investigation with combination effects of Multiple NUI Input modalities, for example the combined input of voice recognition, gaze detection and direct or indirect pointing technology, as a means of controlling a command and control style Interface.

It would be worth creating a software system based on the findings of this research, which carry on from the hardware interface system of this research into the software architecture and the graphical user interface design for the various NUI interfaces.

An experiment which enables the touch-less interaction of the LEAP Motion controller would be beneficial to highlight specific software interfaces that are suitable for the three dimensional interaction of the touch-less controller.

If the Fitts' law study was performed with Indexes of difficulty that lie outside the tested area, as in the experiment performed in this thesis, the index of difficulty was between four and eight. This would show the performance effect of the devices as a much better statistical model and would reinforce the results to adhere to the orginal Law.

Investigating the use of gestures in this manner will also be of use in general, as gestures are the NUI version of issuing a command. In Many computer interaction systems, It generally comprises of either pointing at something, issuing a command or entering some data. So how can we re-design the computer software system to be better for these types of interactions.

As tablet and ubiquitous computing becomes more available and common place, there could be a shift in computing style and occupation for the dispatcher. The dispatcher may see additional roles as more of their task work becomes automated. This will allow them be more active and mobile at depots and Distribution Centers. If used for point to point communication with customers and Couriers, it will allow them the ability to perform their duties at any location in the facility. This could be useful if the dispatcher was required to visually confirm or identify landed freight if it was needed to for quality checks. It could also be used by customers when booking to give better judgement of freight package size.

Another interesting research path would be to create a proprietry system or test software specifically designed for dispatch operations that takes advantage of the multi-touch aspect of the NUI interaction. This would show interesting information about how the software system could be designed to suit the task through a NUI. In theory, this would have been done for this particular investigation, but due to time limitations, this was not possible to execute.

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Appendix A

Demographics & Subjective Results

Participant #	What is your age?	What is your dominant hand?	What is your gender?
1	36	right	male
2	30	right	Male
3	26	Left	male
4	26	Right	Male
5	22	L	M
5	35	R	M
6	22	R	Female
7	32	right	male
8	27	R	male
9	24	R	M
10	31	R	Female
11	23	r	Male
12	25	R	Male
13	27	right	Female
14	23	R	Female
15	23	R	Male
16	26	R	Female
17	26	r	f
18	26	r	f
19	26	R	Male
20	27	R	M
21	30	L	M
22	27	Left	Female
23	24	R	Female
24	26	R	Female
25	20	R	Male
26	28	Right	M

FIGURE A.1: Participant General Computer Experience

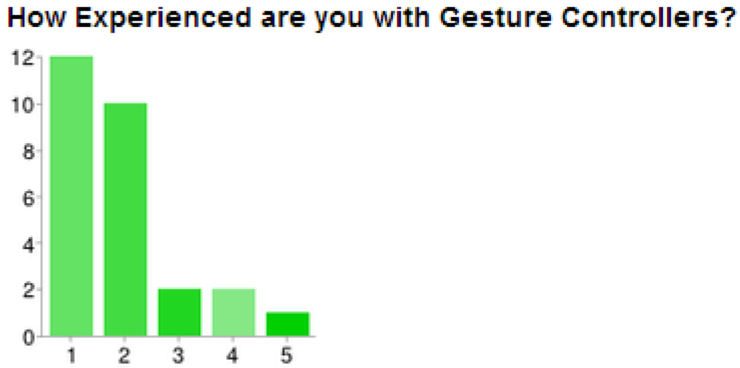


FIGURE A.2: Participant gesture Experience

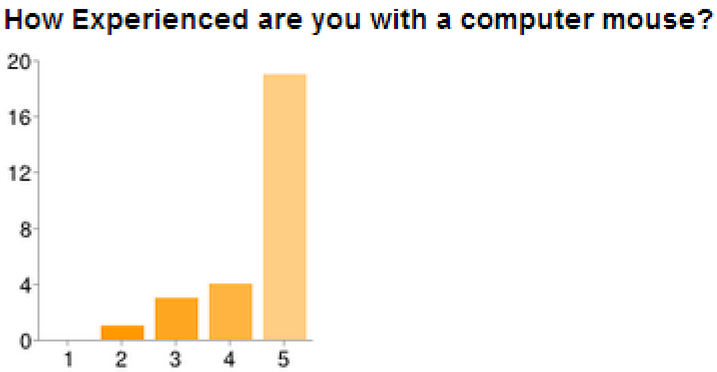


FIGURE A.3: Participant Mouse Experience

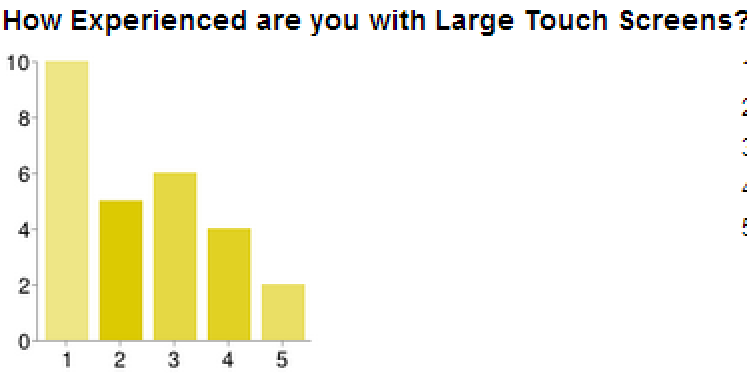


FIGURE A.4: Participant Touch Screen Experience

Appendix B

Tests Results for significance

Cell No.	Tukey HSD test; Approximate Probabilities for Post Hoc Tests Error: Within MSE = 5272E6, df = 72.000				
	CONDITION	Track	Mouse	LEAP	TOUCH
1	TRACK		0.003854	0.000150	0.000329
2	MOUSE	0.003854		0.000150	0.819328
3	LEAP	0.000150	0.000150		0.000150
4	TOUCH	0.000329	0.819328	0.000150	

FIGURE B.1: Tukey Test for siginificant Interaction effects across all Interfaces

Cell No.	Tukey HSD test; Approximate Probabilities for Post Hoc Tests Error: Between; Within; Pooled MSE = 1567E3, df = 11162.													
	DISTANCE CATEGORY	CONDITIO	{1} 1259.5	{2} 974.90	{3} 1926.2	{4} 840.21	{5} 1502.6	{6} 1162.8	{7} 2522.0	{8} 1018.2	{9} 1734.7	{10} 1324.3	{11} 2829.8	{12} 1126.5
1	SMALL	RT TRACK PAD		0.000078	0.000018	0.000018	0.001610	0.881447	0.000018	0.001834	0.000018	0.994504	0.000018	0.498949
2	SMALL	RT MOUSE	0.000078		0.000018	0.465792	0.000018	0.053326	0.000018	0.999854	0.000018	0.000018	0.000018	0.287084
3	SMALL	RT LEAP	0.000018	0.000018		0.000018	0.000018	0.000018	0.000018	0.000018	0.050088	0.000018	0.000018	0.000018
4	SMALL	RT TOUCH	0.000018	0.465792	0.000018		0.000018	0.000019	0.000018	0.087991	0.000018	0.000018	0.000018	0.000080
5	MEDIUM	RT TRACK PAD	0.001610	0.000018	0.000018	0.000018		0.000018	0.000018	0.000018	0.003137	0.081536	0.000018	0.000018
6	MEDIUM	RT MOUSE	0.881447	0.053326	0.000018	0.000019	0.000018		0.000018	0.287230	0.000018	0.175003	0.000018	0.999973
7	MEDIUM	RT LEAP	0.000018	0.000018	0.000018	0.000018	0.000018	0.000018		0.000018	0.000018	0.000018	0.000022	0.000018
8	MEDIUM	RT TOUCH	0.001834	0.999854	0.000018	0.087991	0.000018	0.287230	0.000018		0.000018	0.000023	0.000018	0.768928
9	LARGE	RT TRACK PAD	0.000018	0.000018	0.050088	0.000018	0.003137	0.000018	0.000018	0.000018		0.000018	0.000018	0.000018
10	LARGE	RT MOUSE	0.994504	0.000018	0.000018	0.000018	0.081536	0.175003	0.000018	0.000023	0.000018		0.000018	0.028212
11	LARGE	RT LEAP	0.000018	0.000018	0.000018	0.000018	0.000018	0.000018	0.000022	0.000018	0.000018	0.000018		0.000018
12	LARGE	RT TOUCH	0.498949	0.287084	0.000018	0.000080	0.000018	0.999973	0.000018	0.768928	0.000018	0.028212	0.000018	

FIGURE B.2: Tukey Test for significance between all Interface types and Distances

Cell No.	DISTANCE ACTEGORY	Big/Small	{1} 2884.5	{2} 3042.3	{3} 1716.1	{4} 2192.7	{5} 2481.7	{6} 2733.8
	Tukey HSD test; variable RT (GOOD DATA SORTED) Approximate Probabilities for Post Hoc Tests Error: Between MSE = 5819E3, df = 2794.0							
1	LARGE	big		0.986717	0.000020	0.001420	0.153957	0.945407
2	LARGE	small	0.986717		0.000020	0.002349	0.103539	0.714132
3	SMALL	big	0.000020	0.000020		0.024970	0.000021	0.000020
4	SMALL	small	0.001420	0.002349	0.024970		0.341991	0.002233
5	MEDIUM	big	0.153957	0.103539	0.000021	0.341991		0.379062
6	MEDIUM	small	0.945407	0.714132	0.000020	0.002233	0.379062	

FIGURE B.3: Tukey Test for LEAP

Cell No.	DISTANCE CATEGORY	Big/Small	{1} 1284.1	{2} 1083.3	{3} 1085.6	{4} 921.87	{5} 1408.8	{6} 1255.3
	Tukey HSD test; variable RT (GOOD DATA SORTED) Approximate Probabilities for Post Hoc Tests Error: Between MSE = 1012E2, df = 2794.0							
1	MEDIUM	small		0.000020	0.000020	0.000020	0.000020	0.873235
2	MEDIUM	big	0.000020		0.999998	0.000020	0.000020	0.000020
3	SMALL	small	0.000020	0.999998		0.000020	0.000020	0.000020
4	SMALL	big	0.000020	0.000020	0.000020		0.000020	0.000020
5	LARGE	small	0.000020	0.000020	0.000020	0.000020		0.000021
6	LARGE	big	0.873235	0.000020	0.000020	0.000020	0.000021	

FIGURE B.4: Tukey Test for Mouse

Cell No.	DISTANCE ACTEGORY	Big/Small	{1} 1043.9	{2} 1419.0	{3} 776.28	{4} 947.76	{5} 916.97	{6} 1153.8
	Tukey HSD test; variable RT (GOOD DATA SORTED) Approximate Probabilities for Post Hoc Tests Error: Between MSE = 1318E2, df = 2794.0							
1	LARGE	big		0.000020	0.000020	0.004490	0.000026	0.000181
2	LARGE	small	0.000020		0.000020	0.000020	0.000020	0.000020
3	SMALL	big	0.000020	0.000020		0.000020	0.000020	0.000020
4	SMALL	small	0.004490	0.000020	0.000020		0.717357	0.000020
5	MEDIUM	big	0.000026	0.000020	0.000020	0.717357		0.000020
6	MEDIUM	small	0.000181	0.000020	0.000020	0.000020	0.000020	

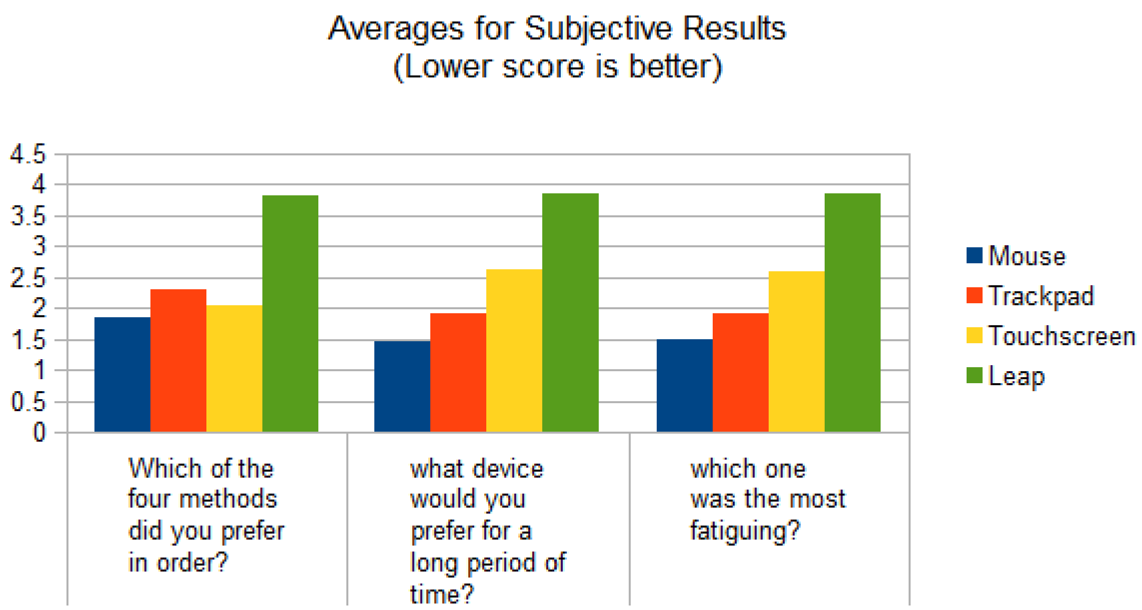
FIGURE B.5: Tukey Test for Touch Screen

Cell No.	DISTANCE CATEGORY	Big/Small	{1} 1665.9	{2} 1415.7	{3} 1398.1	{4} 1188.1	{5} 1846.6	{6} 1615.5
	Tukey HSD test; variable RT TRACK PAD (GOOD DATA SORTED) Approximate Probabilities for Post Hoc Tests Error: Between MSE = 1638E2, df = 2794.0							
1	MEDIUM	small		0.000020	0.000020	0.000020	0.000020	0.639610
2	MEDIUM	big	0.000020		0.990423	0.000020	0.000020	0.000020
3	SMALL	small	0.000020	0.990423		0.000020	0.000020	0.000020
4	SMALL	big	0.000020	0.000020	0.000020		0.000020	0.000020
5	LARGE	small	0.000020	0.000020	0.000020	0.000020		0.000020
6	LARGE	big	0.639610	0.000020	0.000020	0.000020	0.000020	

FIGURE B.6: Tukey Test for Trackpad

Appendix C

Subjective Results



	Mouse	Trackpad	Touchscreen	Leap
Which of the four methods did you prefer in order?	1.8461538462	2.3076923077	2.0384615385	3.8076923077
What device would you prefer for a long period of time?	1.4487179487	1.9010989011	2.6007326007	3.8516483516
Which device was the most fatiguing?	1.4711538462	1.8961538462	2.5807692308	3.8442307692

Figure C.1: Results from Post Experiment Subjective Analysis

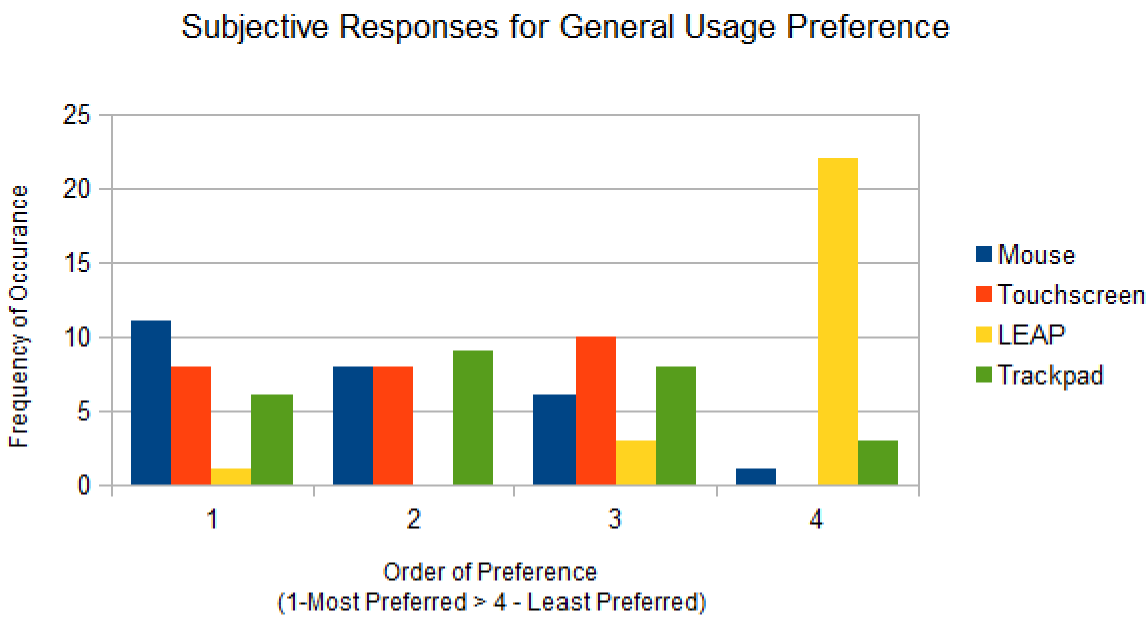


FIGURE C.2: Results for subjective questionnaire, Which of the four interaction methods did you prefer to use in order of preference?

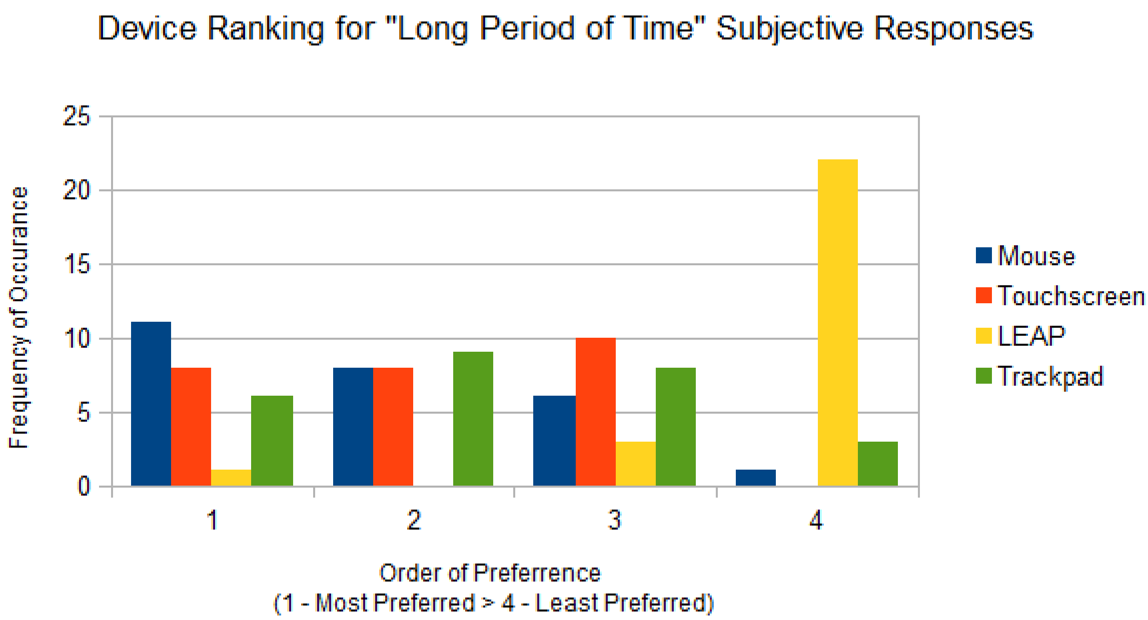


FIGURE C.3: Results for subjective questionnaire, What device would you prefer to use for a long period of time?

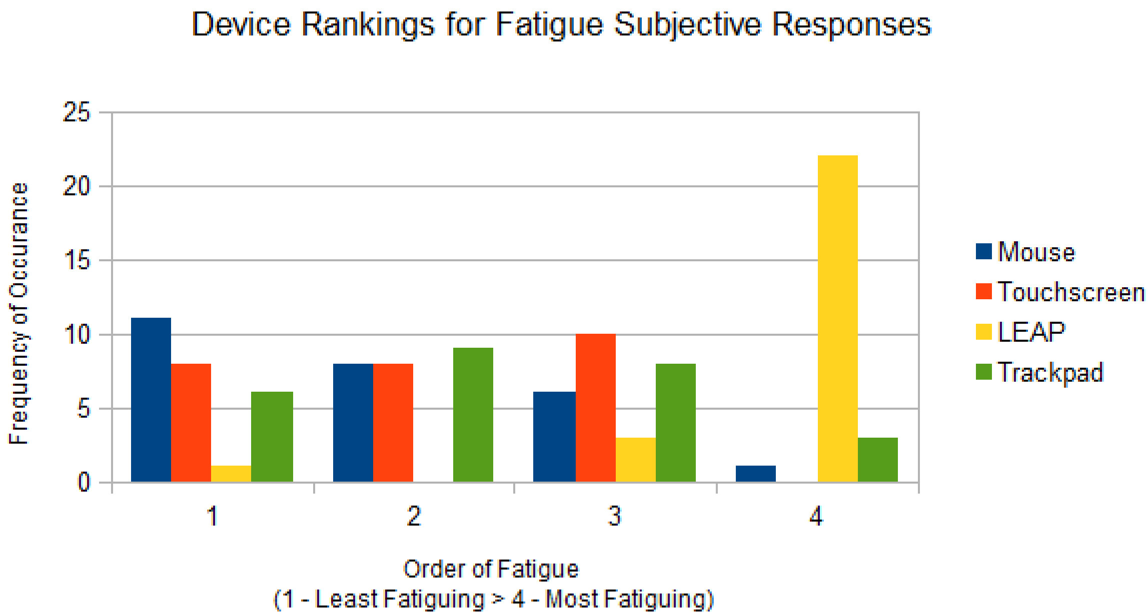


Figure C.4: Results for subjective questionnaire, What did you find most fatiguing?

Appendix D

Questionnaires

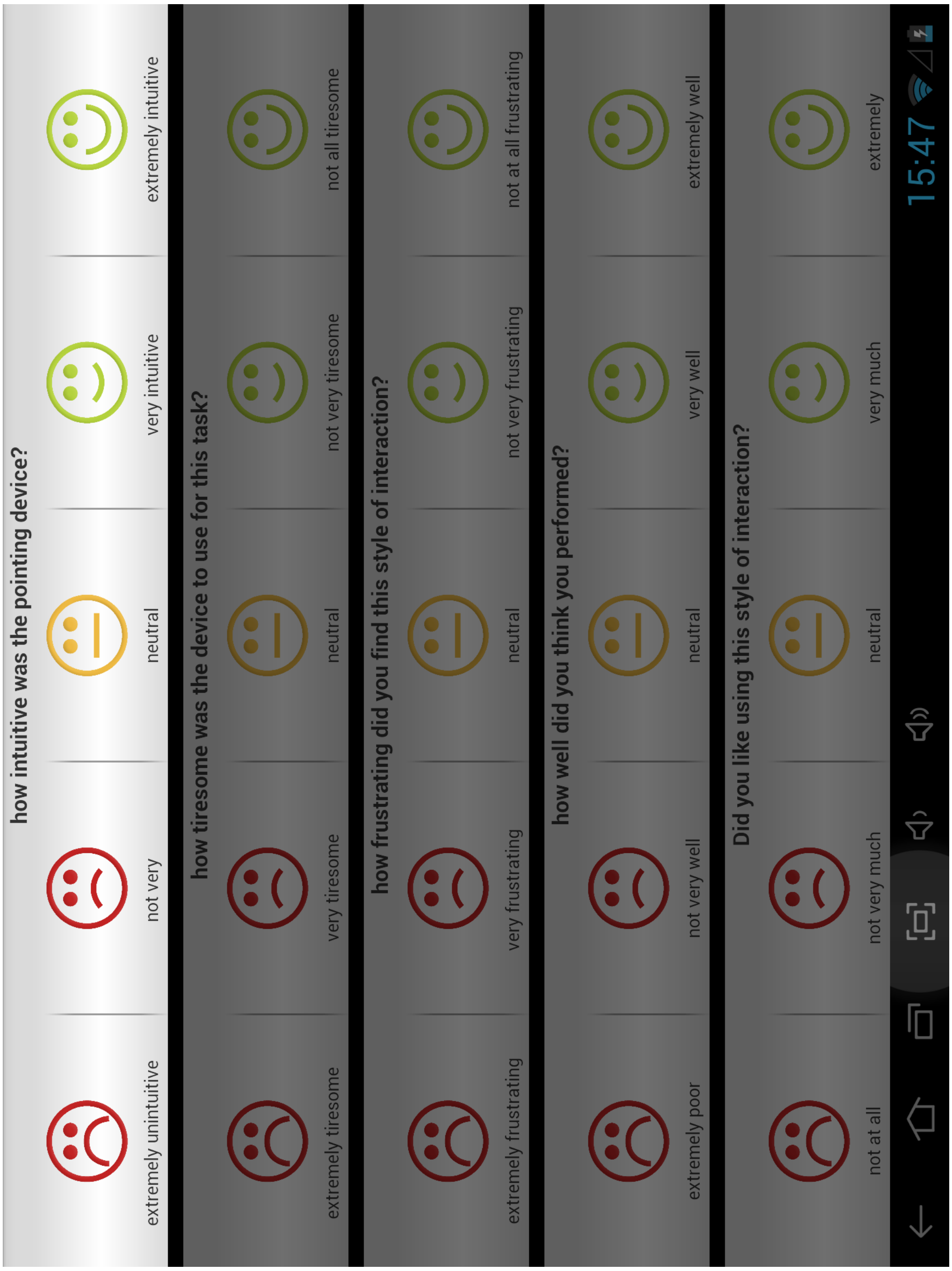


Figure D.1: Likert Scaled Questionnaire on Tablet

Pointing Experiment Pre-Questionnaire

Welcome to the Pointing experiment, Please answer the following questions below before performing the experiment.

Participant #

What is your age?

What is your dominant hand?
L R or AMBI

What is your gender?

How experienced are you with computers?

	1	2	3	4	5	
Not Very	○	○	○	○	○	Very

How Experienced are you with a computer mouse?

	1	2	3	4	5	
Not Very	○	○	○	○	○	Very

How Experienced are you with a track pad?
i.e. the trackpad on a laptop

	1	2	3	4	5	
Not Very	○	○	○	○	○	Very

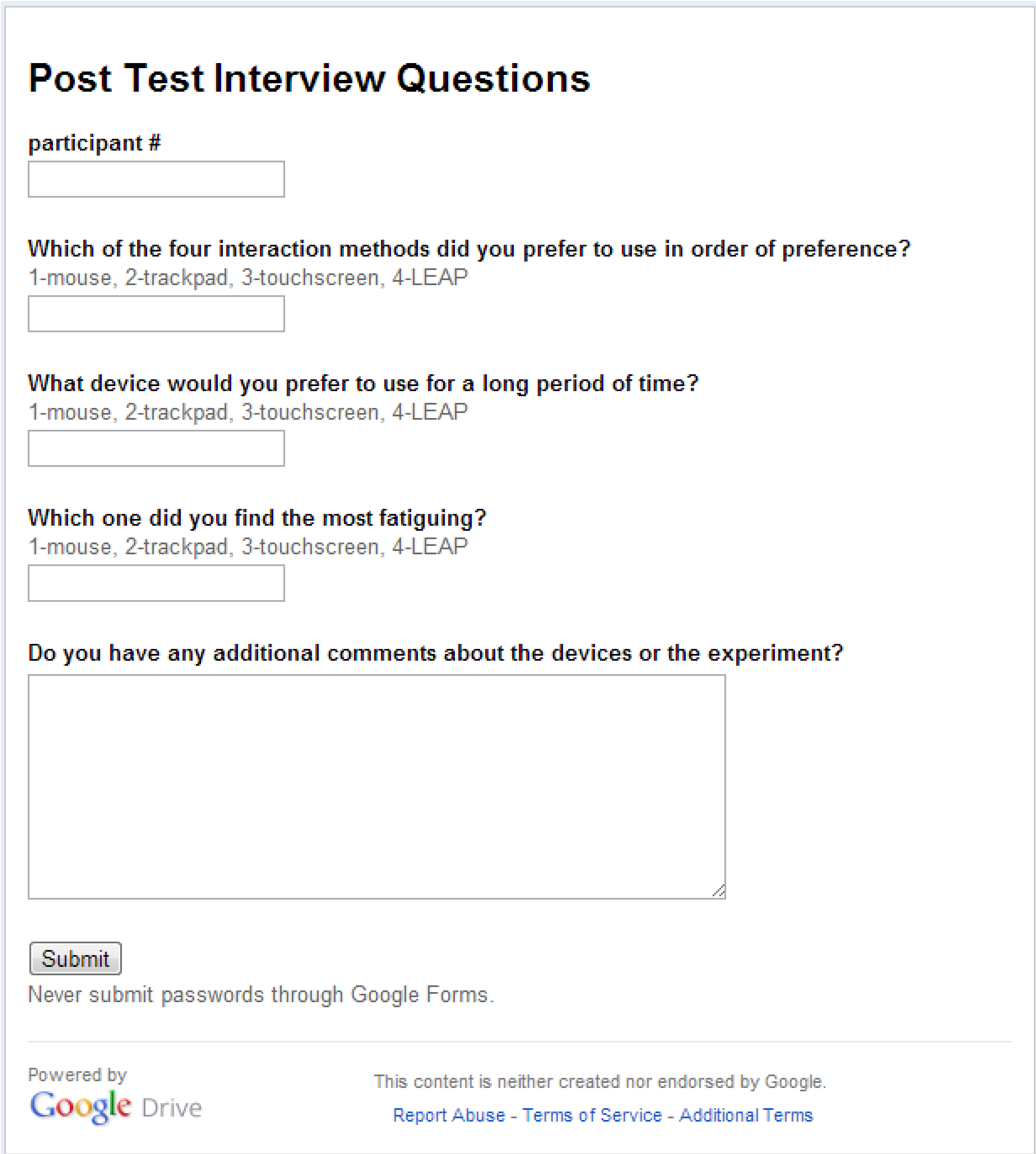
How Experienced are you with Large Touch Screens?
not including mobile phones

	1	2	3	4	5	
Not Very	○	○	○	○	○	Very

How Experienced are you with Gesture Controllers?
I.e. Kinect, or Eye Toy etc.

	1	2	3	4	5	
Not Very	○	○	○	○	○	Very

Submit



Post Test Interview Questions

participant #

Which of the four interaction methods did you prefer to use in order of preference?
1-mouse, 2-trackpad, 3-touchscreen, 4-LEAP

What device would you prefer to use for a long period of time?
1-mouse, 2-trackpad, 3-touchscreen, 4-LEAP

Which one did you find the most fatiguing?
1-mouse, 2-trackpad, 3-touchscreen, 4-LEAP

Do you have any additional comments about the devices or the experiment?

Submit

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Figure D.3: Questionnaire for Post Experiment

Appendix E

Computer Details

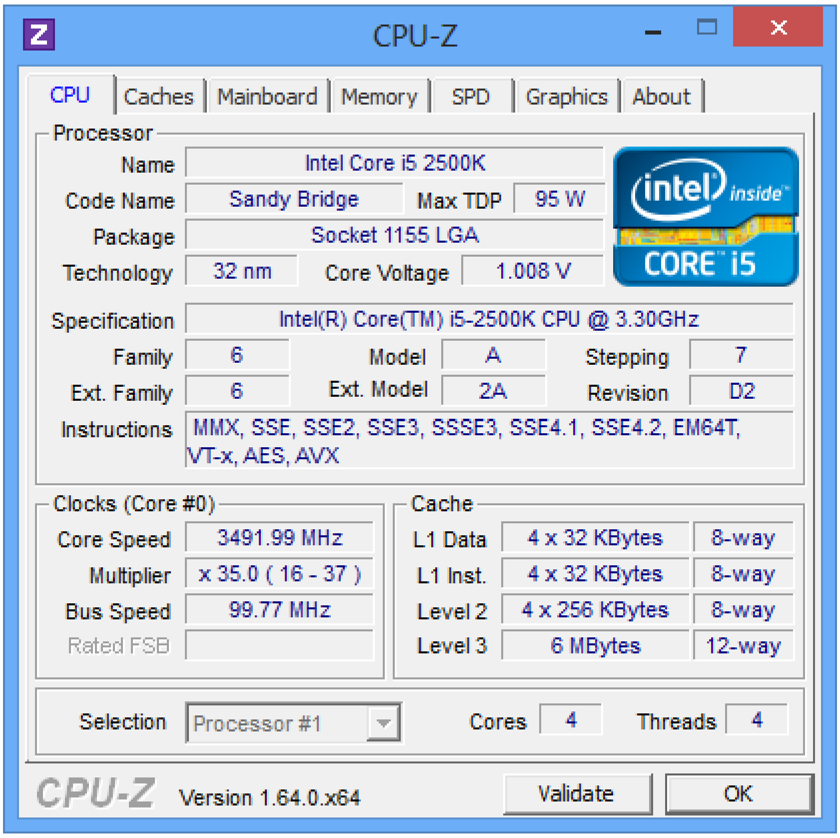

FIGURE E.1: Processor Specifications

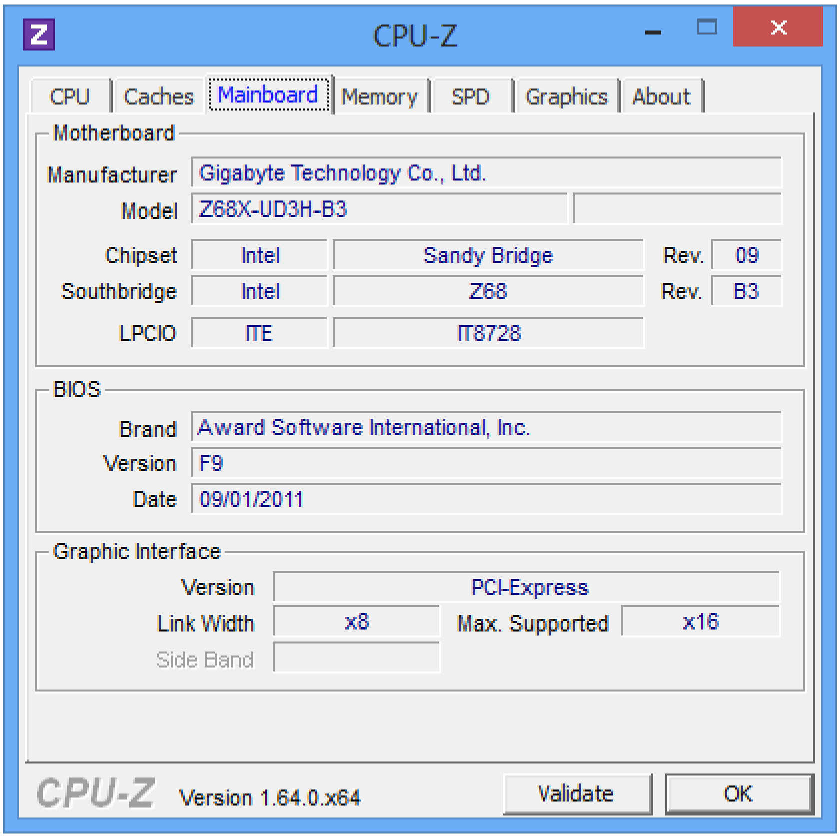

FIGURE E.2: Motherboard Specifications

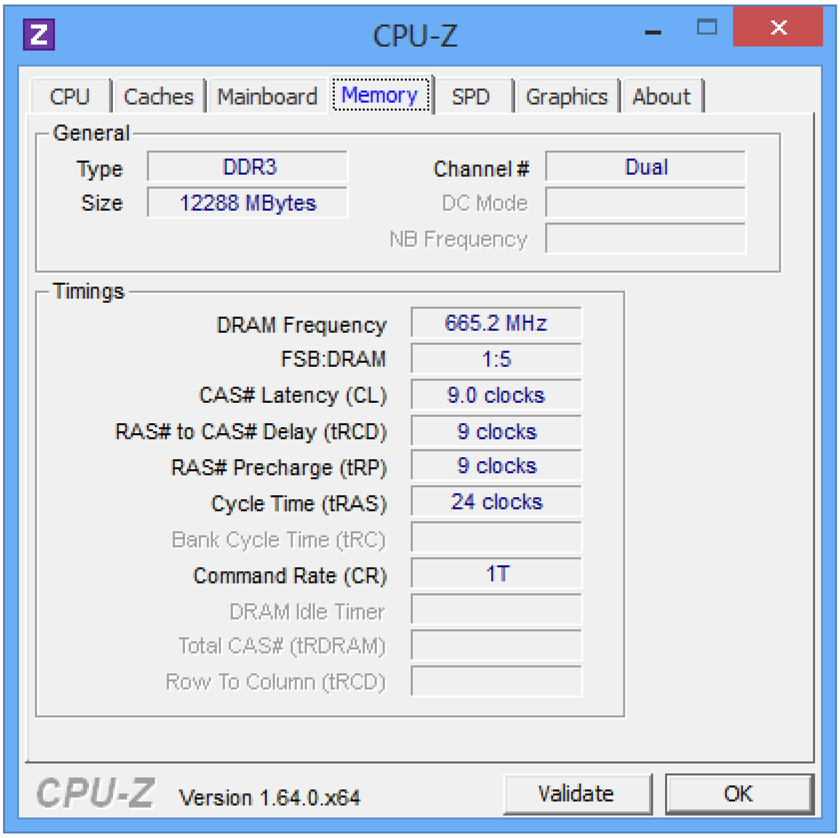

FIGURE E.3: Memory Specifications

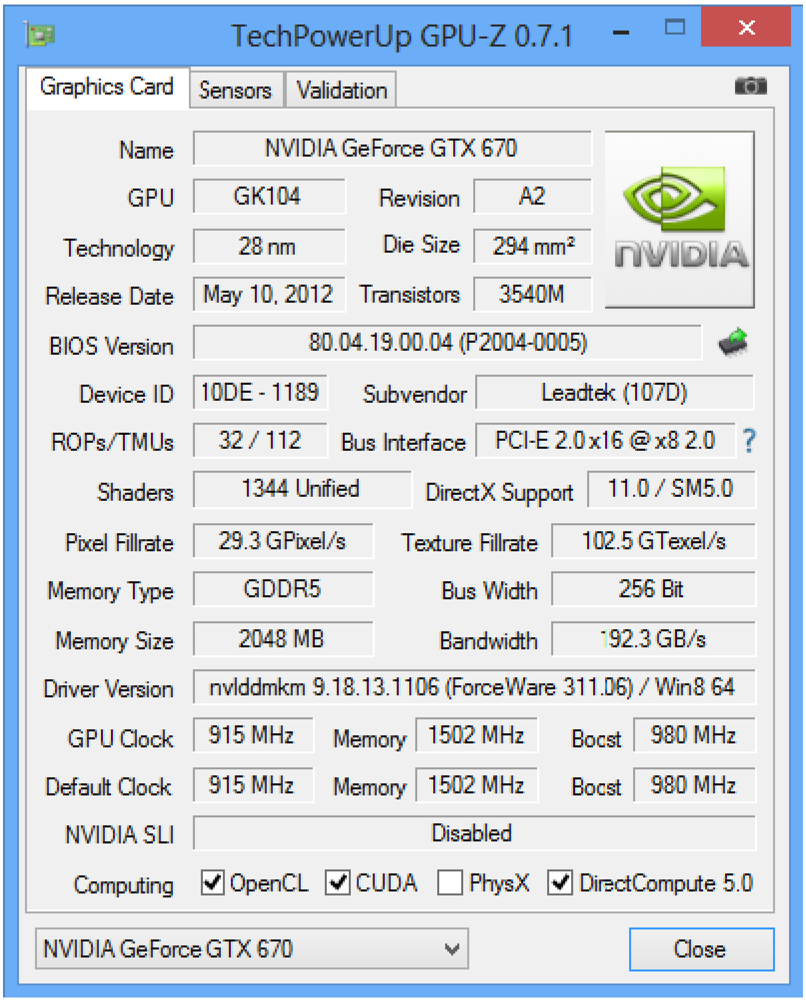

FIGURE E.4: Graphics Card Specifications

Appendix F

Touchscreen Overlay Details

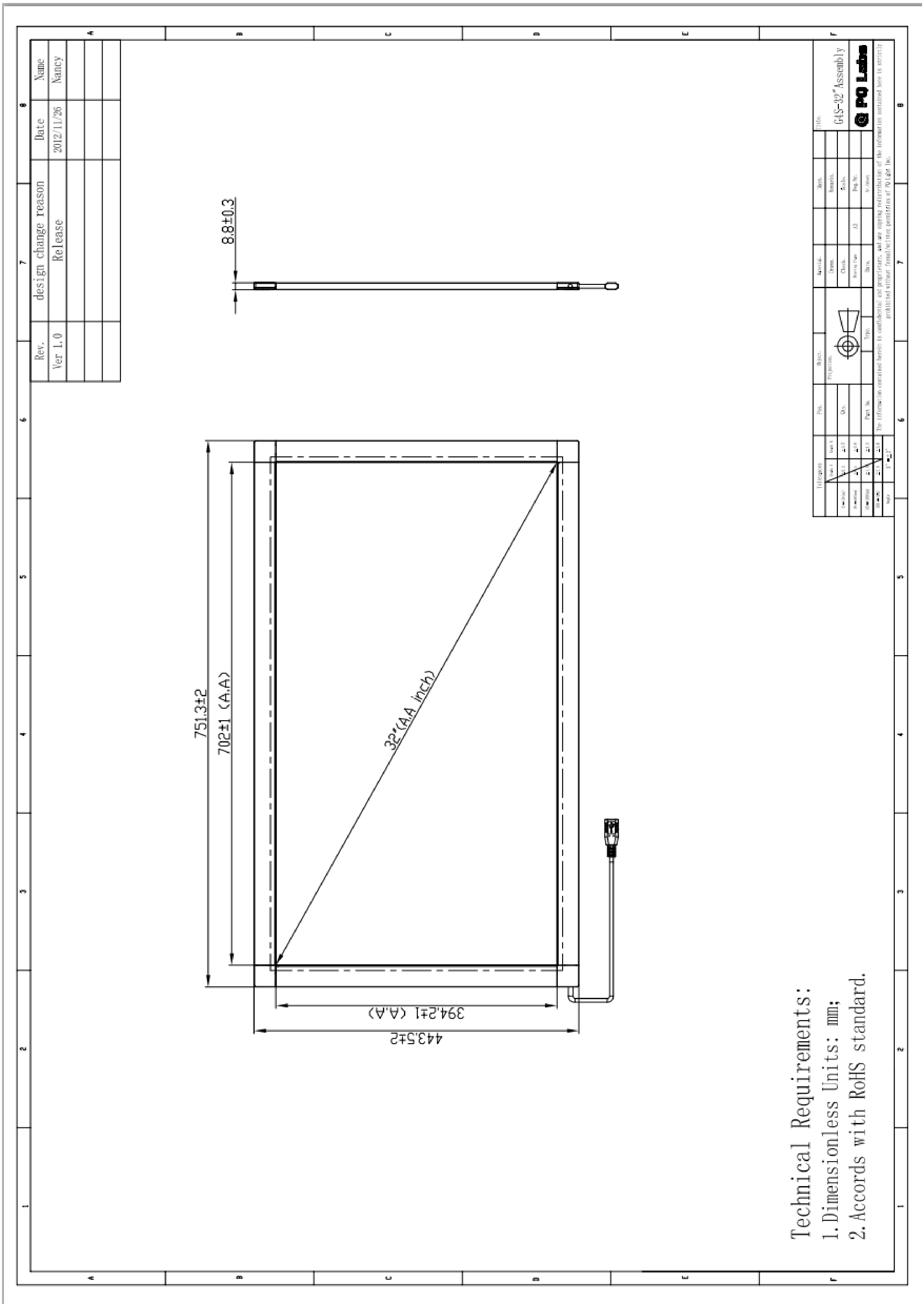

FIGURE F.1: PQ Labs touchcreen Specification

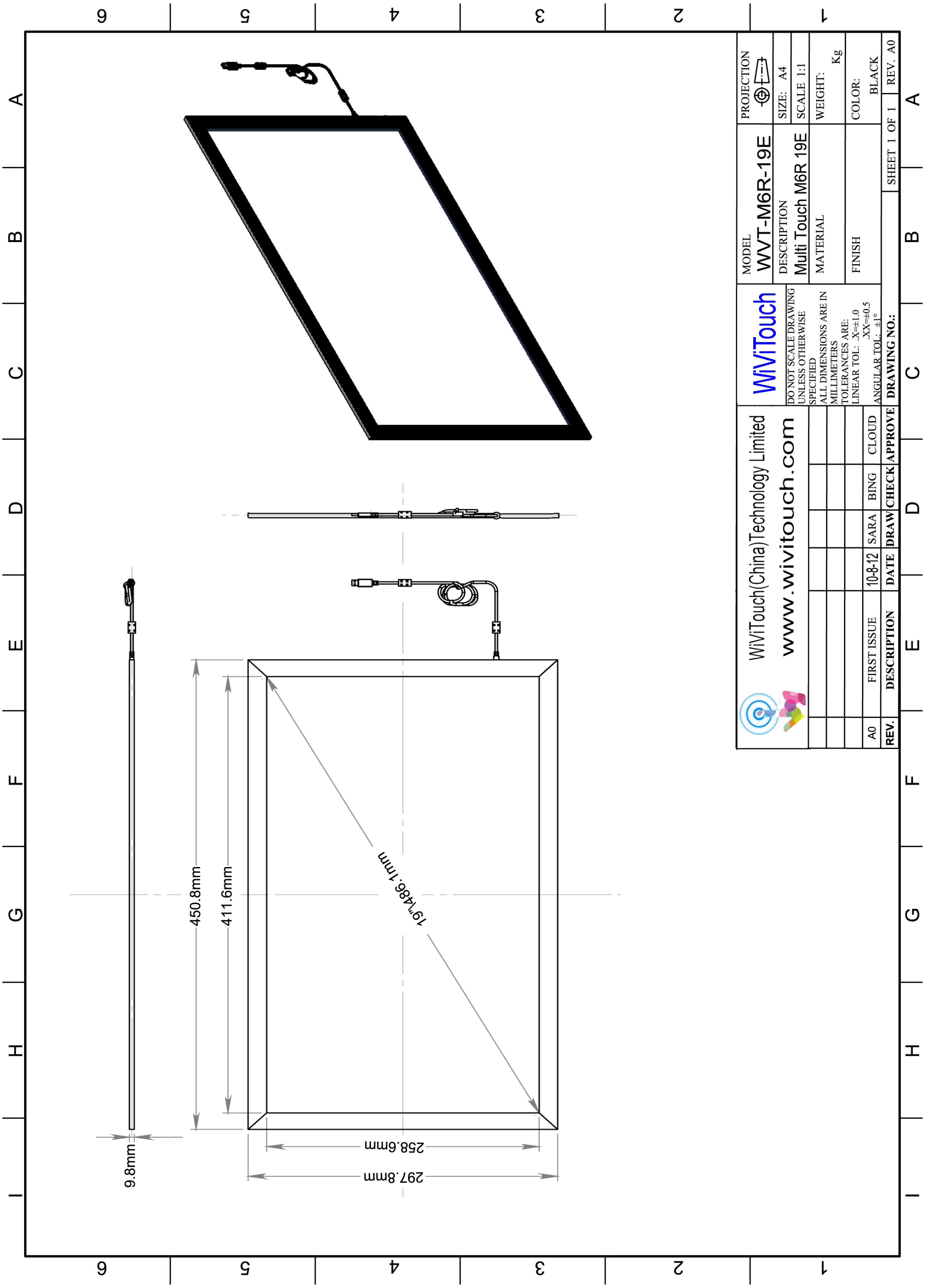

FIGURE F.2: WiviTouch touchcreen Specification

Appendix G

Information Sheet and Consent Form

University of Canterbury Private Bag 4800 Christchurch Telephone (64 3) 364 2349 Fax (64 3) 364 2095 Website www.hitlabnz.org

INFORMATION FORM

RESEARCH STUDY: The effectiveness of Natural User Interface and Multi-Display Technology for Dispatcher Task Handling.

INVESTIGATORS: Rory M.S. Clifford, Prof Mark Billinghurst, Prof. Tom Furness, Dr Andreas Dünser.

You are invited to participate in the research paper entitled: The effectiveness of Natural User Interface and Multi-Display Technology for Courier Dispatch Task handling.

The aim of this project is to evaluate the effectiveness of Natural User Interface technologies, some which are pre-existent and one of which has not been released for domestic use to date. To do this we will compare the technologies using a set of pointing tasks and record the response times that you, the participant, make while using the devices.

The pointing task is known as the Fitts' pointing experiment, which was first designed by Paul Fitts in the 1960's and has been continuously referred to and evaluated against for a variety of computer and non-computer experiments.

Your participation in this experiment will require you to use the each of the interface devices to point at the targets presented to you on the computer display system. You will be given a period of time to learn how to use the interface devices before starting the experimental trials. In the trials, you will be presented two targets, where the goal for you is to select both of these targets as quickly as possible. You will be presented a total of 113 targets for each interface type, which after some duration may induce fatigue, so you will be given 5 minute rest periods in between the different experimental device types. There is a list of 4 device types in this experiment which you will use as a pointing controller. These are as follows; a standardized computer mouse controller, a laptop like wireless trackpad controller, a large Multi-Touch Display controller and finally a three dimensional touch-less hand and finger tracking controller.

You will be required to fill out a short questionnaire at the beginning and at the end of the experimental session.

In order to be eligible for this study we require that you do not have any health issues related to physical exertion or any repetitive stress injury (RSI).

You may, at any time request to withdraw from the experiment for any reason with no consequence and your participation in the experiment will be terminated.

The following items are possible risks. Please read carefully.

Your participation in the experiment will require about one hour. Because of the nature of the task, you may find that you will experience some level of fatigue. While all action has been taken to ensure that this is not to cause any injury, it must be mentioned in case if you are at risk of chronic health issues such as RSI. If there is any concern about this then please inform the researcher immediately to withdraw the experiment. Do note that you will be given sufficient rest time between trials.

Upon the completion of your involvement in this study, we will also provide you with a $5 gift voucher.

The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in this investigation: the identity of the participants will not be made public without their consent. To ensure anonymity and confidentiality, only the researchers will be allowed access to the video recordings of the participants. The recordings will be destroyed after a period of 5 years. They will be put in a secure and encrypted location that requires a password to gain access. The only individuals with the password will be the researchers in the study. Furthermore, the collected research data will also be kept in a secure and locked location. Only the researchers will have access to it via a key.

The project is being carried out as a research project by Rory Clifford, under the supervision of Prof. Mark Billinghurst and Prof. Tom Furness, who can be contacted by the following means. They will be pleased to discuss any concerns you may have about participation in the project.

Rory M.S. Clifford

HIT Lab NZ, University of Canterbury

email: rory.clifford@pg.canterbury.ac.nz

Prof Mark Billinghurst

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Prof. Tom Furness

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Dr Andreas Dünser.

HIT Lab NZ, University of Canterbury

Email: andreas.duenser@hitlabnz.org

This proposal has been reviewed and approved by the Human Interface Technology Laboratory, University of Canterbury and the University of Canterbury Human Ethics Committee Low Risk process.

please take this form with you when you leave.

CONSENT FORM

RESEARCH STUDY: The effectiveness of Natural User Interface and Multi-Display Technology for Dispatcher Task Handling.

INVESTIGATORS:

Rory M.S. Clifford

HIT Lab NZ, University of Canterbury

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Prof. Mark Billinghurst

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Dr Andreas Dünser.

HIT Lab NZ, University of Canterbury

Email: andreas.duenser@hitlabnz.org

I have read and understood the description of the above-named project. On this basis I agree to participate voluntarily as a subject in the project, and I consent to publication of the results of the project with the understanding that anonymity will be preserved. The data will be kept for up to 5 years before being destroyed.

I understand that I will be recorded during the experiment, but the recording will only be viewed by researchers directly associated with the project. I also understand that the recording will be kept for up to 5 years before being destroyed.

I understand also that I may at any time withdraw from the project, including withdrawal of any information I have provided.

I note that the project has been reviewed ***and approved*** by the University of Canterbury Human Ethics Committee.

______________________	______________	_______
Participant (Print name)	Signature	Date

HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2013/13/LR

27 March 2013

Rory Clifford
HIT Lab
UNIVERSITY OF CANTERBURY

Dear Rory

Thank you for forwarding your Human Ethics Committee Low Risk application for your research proposal “The effectiveness of natural user interface and multi-display technology for courier dispatch tasks”.

I am pleased to advise that this application has been reviewed and I confirm support of the Department’s approval for this project.

With best wishes for your project.

Yours sincerely

Lindsey MacDonald
Chair, Human Ethics Committee